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EXPERT CONSULTATION ON THE REGULATION OF FISHING EFFORT (FISHING MORTALITY)

Rome, 17-26 January 1983

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

PAPERS PRESENTED

at the

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Rome, 17-26 January 1983

A Preparatory Meeting for the FAO World Conference on Fisheries Management and Development

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1984

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PREPARATION OF THIS DOCUMENT

An Expert Consultation on the Regulation of Fishing Effort was convened by FAO in Rome, 17-26 January 1983, as one of the preparatory meetings for the World Conference. The purpose of the Consultation was to review the experiences of countries with fisheries management techniques. The report of the Consultation, as approved by the participants at the conclusion of the meeting, was distributed in 1983. The papers presented at the Consultation have been prepared as supplements to the Report. The first supplement contains the abstracts of the papers in three languages: English, French and Spanish. This document is Supplement 2 and contains those papers that specifically relate to the theoretical aspects of fisheries management and its practice in a general manner. Supplement 3 contains those papers that cover the management approaches adopted and experiences by individual countries. Supplements 2 and 3 are available in English only.

Abstract

The papers contained in this supplement cover theoretical aspects of fisheries management and its practice in a general manner. Two aspects of fisheries management are reviewed from the perspective of the market for fish and from the fishermen's view. The majority of the papers discuss specific regulatory techniques such as fixed fishing gear, selectivity of fishing gears including mesh size regulation, controls over numbers of fishing vessels and the effects of various financial measures. Several of the papers examine approaches to fisheries regulation that attempt to overcome the common property aspect of fisheries resources. The last paper re-examines the basic equilibrium theory that is applied to most fisheries.

Distribution :

Participants
FAO Fisheries Department
FAO Regional Officers
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EDITORIAL NOTE

The papers contributed to the Expert Consultation on the Regulation of Fishing Effort (Fishing Mortality), convened by the Fisheries Department of FAO at Rome during January 17-26, 1983, fall more or less distinctly into three divisions or groups. There is, firstly, a group of 15 papers dealing with theoretical aspects of fishery management and with its practice in a broad and general manner. The remaining papers, roughly two dozen in number, are about equally divided between, (a) a group describing the approaches adopted and the problems encountered by individual countries in the design and implementation of fishery-management programmes, and (b) a group in which experience in the management of particular fisheries is described. Certain of the papers in the last-mentioned group might be defined as reports of case studies.

The division into three groups is by no means absolute, of course. Even in the first group of papers, one finds frequent reference to specific fisheries and this tendency is stronger still in the case of the second group. Per contra, several papers in the second and third groups are of theoretical as well as analytical significance. In one or two instances, also, selection as between groups two and three presented some difficulty. Nevertheless, based on the various writers' major theme or focus of interest, the classification is justifiable and useful.

Some explanation of the order in which the papers are arranged perhaps is necessary. Within the first group, the first three papers set the stage, as it were, and the remainder follow an order reflecting the evolvement of approaches to fishery management. The papers in the second group are listed geographically - from Europe, through North America to the Far East - illustrating convergence as well as differentiation in the approaches evolved in varying physical, socio-economic, cultural and political environments. In the third group of papers, although largely supplementary to those in the preceding group, the arrangement is by author (alphabetically).

In preparing these papers for publication, textual emendation has been minimal. Approximately a half dozen papers, by authors writing in English as a foreign language, required substantial revision of grammar and usage. In a few other cases, clarification of the text necessitated a change of phrasing or terminology, which was undertaken with the guidance of participants in the Consultation. Otherwise, revision has been restricted to the correction of typographical errors and the like. Minor details and other attempts have been made to impose a uniform style or structure (paragraphing, etc.) on these papers.

W.C. MacKenzie
Ottawa
(December 1983)

CONTENTS

Author	Title	Pages
Gulland, J.A.	Introduction: Some notes for the Consultation on the Regulation of Fishing Effort	1-7
MacSween, I.	The interaction between fisheries management and the marketing of fish	9-19
Thompson, D.B.	Fishermen and Fisheries Management	21-39
McGoodwin, J.R.	Some examples of self-regulatory mechanisms in unmanaged fisheries	41-61
Caddy, J.F.	Indirect approaches to regulation of fishing effort	63-75
Skud, B.E.	Manipulation of fixed gear and the effect on catch-per-unit effort	77-85
Jones, R.	Mesh size regulation and its role in fisheries management	87-103
Thompson, D.B. and Ben-Yami, M.	Fishing gear selectivity and performance	105-118
Gulland, J.A.	Control of the amount of fishing by catch limits	119-127
Pope, J.G.	Notes on the scientific problems of TAC management	129-147
Brochmann, B.S.	Regulation of fishing effort through vessel licences	149-151
Panayotou, J.	Territorial use rights in fisheries	153-160
Doucet, F.J.	Fishermen's quotas: a method of controlling fishing effort	161-165
Brochmann, B.S.	Financial measures to regulate effort	167-172
Caddy, J.F.	An alternative to equilibrium theory for management of fisheries	173-214

INTRODUCTION: SOME NOTES FOR THE CONSULTATION ON THE REGULATION OF FISHING EFFORT

by

J.A. Gulland
Marine Resources Service
FAO Fisheries Department
Rome, Italy

FOREWORD

The purpose of the Consultation

The need for the Consultation arose from two observations - that the well-being of many fisheries requires some control of the amount of fishing (fishing mortality or fishing effort), and that many of the actions that have been taken to regulate fishing effort have not improved the well-being of the fisheries concerned.

There are a number of reasons for this failure, but for the purposes of the Consultation the most important arise from the lack of communication between different groups (scientists, economists, administrators, and of course those in the actual fishing business from the fisherman on a small boat to the owner of a fleet of factory trawlers). As a result most of the analyses carried out and most of the actions taken deal with only part of the problem. The complexities of managing fisheries are such that the result of tackling one part of the problem is to exacerbate the difficulties in other parts, thus reducing or even eliminating any benefits obtained. This lack of communication is also becoming more apparent between the theoretical and practical side of fishery management. Too much of current theoretical work is concerned either with the detailed analysis of one sector (e.g. the dynamics of fish stocks and the environment), or with the development of some description of how fisheries should be managed perfectly, which has little relevance to current practical problems. Commonly, too much time of those engaged in the practical side is taken up with actions dealing with immediate problems (e.g. regulations in allocating next year's catch quota). No time is left to consider whether anything is being done to resolve the medium- to long-term problems. As a result each year the same short-term problems tend to re-appear, getting worse each time.

It is not the intention at this Consultation to design (yet again?) the perfect system of fisheries management. Nor is it intended to provide immediate solutions to the problems of managing say the shrimp fisheries of the Gulf of Carpentaria. Its purpose may be deduced from the views of many thoughtful fishery managers throughout the world: "Surely there is a better way of doing things than what we are doing now".

This is the point where it may be useful to consider the validity of the pair of observations at the start of this paper. The first is certainly true in theory, and there is a massive biological and economic literature to establish the point. It is also true in practice to the extent that without control of the amount of fishing, virtually all the large fisheries of the world have run into difficulties. The second observation is also also true as an observation of general practical experience. A pessimist might therefore conclude that fisheries are just too difficult to manage, and whatever the theoretical benefits of controlling fishing effort, they will never be achieved in practice. There is some weight in this view. There are probably a number of fisheries where the potential benefits from controlling effort are so small, and the practical difficulties so large, that it would not be worth while attempting to manage these fisheries. One of the first steps in considering management is to determine not only the potential benefits from effort control, but also to determine whether there is a reasonable hope of achieving a certain proportion of those benefits, and whether the costs of doing so will be less than the actual benefits achieved.

Experience suggests that this hope should exist in many fisheries. Changes in the Law of the Sea have removed, for a large number of fisheries, the need to achieve implementation of management actions through international agreement between an indeterminate number of countries. In the past, even where such agreement was reached, it had often been reached at the lowest common denominator, and involved small benefits and high transaction costs. Now many stocks are the concern of a single country. The government of that country has the legal power to impose any management scheme which seems appropriate to the national interest. Of course having the legal power does not necessarily mean that any regulation can easily be imposed and enforced. Also in several countries with a federal constitution there remain problems of jurisdiction between the central government and the state or provincial government. Despite these problems, some of the greatest obstacles in the way of effective management have been removed for the many stocks that now lie wholly within a single national jurisdiction.

The same is also true, albeit to a somewhat lesser extent, for those fish which cross the boundaries between national EEZs. These stocks are shared between several countries; however, the number of countries is usually small - often only two - and there is no risk of extra countries entering the fishery, and thus upsetting the agreements reached between those already in the fishery. The biological and other characteristics of the stock, vis-a-vis the national EEZs (e.g. where the spawning grounds are, how much of the total catch is taken in each EEZ) provide some objective basis for reaching agreement as to how the stock should be managed, and the potential benefits divided between the interested countries. Managing shared stocks under the new Law of the Sea may be difficult, but it is definitely easier than managing the open-access international fisheries in the previous era.

Nevertheless, despite the increased powers of government, and despite the wide-spread recognition by individual governments that management, and the control of the amount of fishing, is needed in many of their fisheries, not much has been done. Many reasons can be put forward in respect of one or other fishery - poor statistics, inadequate knowledge of the biology of the fish, lack of information on the long-term economic impact of alternative management measures, inadequate legal powers, pressures by strong political forces against what would seem to be the best measures, insufficient administrative powers to enforce unpopular measures, etc. These are often excuses more than real causes. One underlying reason is, as mentioned earlier, poor communication between the different groups (scientists, administrators, fishermen, etc.) directly concerned with a national fishery, and also between the theoreticians and the actual practitioners of management.

As a result governments find it difficult to determine either qualitatively or quantitatively the management measure appropriate to the particular conditions of their fisheries. By qualitative is meant the type of measure - catch quota, fiscal measures, limits on the number or type of vessel and the gear used, etc. By quantitative is meant the precise level - the tonnage of the annual catch quota, the number of 200-gross ton trawlers that should be allowed to fish, etc. This Consultation is concentrating on the qualitative aspects. By exploring the various aspects, advantages and disadvantages, of each approach, the proceedings should provide governments with useful guidance on the approaches most appropriate to their individual conditions. Determination of the quantitative aspects of management requires examination of the actual conditions of the fishery, though it is hoped that even in this the Consultation will provide guidance on the nature of investigations that are needed. The specific attributes of individual approaches (catch quotas, etc.) are examined in later papers. This paper largely outlines the objective of management, and the criteria against which the success or failure of a management scheme can be judged.

Objectives

There are several possible objectives in managing fisheries, and some of them are inconsistent. It is not possible, given a limited resource, to maximize employment in a fishery, and at the same time maximize the average income of the individual fisherman. It is essential that any management should be based on a reasonably clear idea of what the objective (or objectives) are, and if there are several, of the relative priorities between them.

This does not mean that before starting to implement any management measure, the objectives have to be explicitly spelt out in detail. Indeed some of the bigger difficulties have come when a detailed objective has been set down, and later found to be inappropriate because of changed priorities, or technical difficulties in complying with the details. The International Whaling

Commission's problems first with the Maximum Sustainable Yield, and then with the New Management Procedure could serve as a warning. In contrast some of the more successful examples of management have come when there are no explicit objectives, other than a desire on the part of the Director of Fisheries that, over a period of years, his life should be as peaceful as possible. It should be disturbed as little as possible by angry complaints from fishermen, politicians or others. This can be achieved only by a recognition of what matters are likely to raise most complaints (i.e. which are the main objectives of fishermen, politicians, or others) and that long-term peace requires on occasion some short-term trouble when a necessary but (at least in the short-term) unpopular measure is introduced.

Neither this paper nor the Consultation as a whole is intended to provide a prescription of what the objectives of management should be - even if this were theoretically possible, given the diversity of interest between countries, and even between regions within countries. Determination of objectives is a national matter. It should always be done, though it may well be more convenient for the expression of objectives to be implicit rather than explicit. If explicit it again may be better to leave the definitions somewhat general, provided the objectives are sufficiently well defined to enable the subsequent performance of management to be checked against these objectives.

The intention of this paper is, having stressed the importance of recognizing the objectives, to review the types of objectives that can be chosen, and the related measures against which the success of management can be measured. These objectives fall into three groups: the resources, economic performance, and equity. In addition the transaction costs, e.g., the burden on limited administration or scientific resources, form a fourth group of measures of the usefulness of a particular measure.

Resources and biological yield

A productive fish stock and high level of yield are necessary conditions for successful management. They are not sufficient ones. Nor does the need for a high yield mean that managers should try to maximize the biological yield from the stock, or that a fishery in which the yield is somewhat below the theoretical maximum is not being successfully managed.

Though the Maximum Sustainable Yield (MSY) is not a good management objective, some of the extensive criticisms of MSY are misplaced. MSY has only rarely been used as the principal guide to actual management decisions. Its greatest practical value has been as part of a simple model of the biological facts on which management is based. By talking about MSY and the dangers of exceeding MSY, policy makers and others can appreciate that too much fishing can reduce the yield, and that in a heavily fished stock fishing less can mean catching more. In fact, for some of the cases where MSY seems to have been used as the objective, this has not been the case. Thus, especially round the North Sea, scientists have had to recommend catch quotas without explicit guidance from the decision makers on their target objective. In these cases the fishing mortality giving the maximum yield per recruit has provided an objectively definable target, which can be used by the biologists in reaching a specific figure for the recommended catch for next year. However, it will only give the MSY if the average recruitment does not vary. It may well be excess of the fishing mortality giving the MSY, which may be closer, for example, to $F_{0.1}$.

So far as the impact on the resources are concerned, many of the most important differences between approaches to management lie in the unexpected effects. If fish stocks and the impact of different amounts of fishing followed the simple assumptions, then any management measure likely to be considered will have much the same effect. It should result in increased abundance (compared with an unmanaged fishery) and high catches. In practice fish stocks vary, and fishermen change their methods. Unless the management measures are adapted to take these changes into account, the effect on the stocks and future catches could be very different from that expected. A constant catch quota, set according to average stock abundance could lead to severe over-fishing in periods when abundance is low for natural reasons. A fixed number of vessels will lead to progressive over-fishing if no account is taken of improvements in the fleet (bigger vessels, more efficient gear, etc.).

A biological complication that is most talked about but rarely taken into explicit account in setting management measures concerns the interaction between fish species. Such interaction can be biological (e.g. one species feeding on another), or at the fishery level (e.g. one species being caught incidentally by vessels fishing primarily for other species). So that the work of the Consultation can focus on the sufficiently complex problems of controlling effort in a single species fishery, multi-

species aspects will not be discussed except in passing. It must however be recognized that there will be differences between different approaches in the degree to which their impacts can be accurately concentrated on the particular species of concern, and on the ability of the fishing fleets to move from one species to another.

A good management measure is one that can accommodate departures from the single model with minimum adjustment. Thus a limit on the number of vessels may need little adjustment of abundance changes; catch quotas are not affected if the efficiency of the fishing fleet increases. A second consideration is the ease with which the information needed to make the appropriate adjustment can be collected and the adjustment made. This may be considered as part of the transaction costs discussed in a later sector.

Efficiency and economic performance

Nearly all the objectives of management are, in one form or another, economic. Economic indices of one kind or another are likely to be among the most useful tests of the success of a management regime. Nevertheless, perhaps because the emphasis has been placed on maintaining the biological production, the economic impact of many regulations has been to reduce the total value added by the fishery, either by increasing costs or reducing the final value of the product. In many cases the reduction in net value added, well below the level that might have been obtained with other approaches to management, must be taken as an indication of a serious failure by managers.

This is not to imply that maximization of net value added is the only objective, or that the fact that it is below some theoretical maximum obtainable under perfect conditions, should be taken as an indication of failure. It is the fact that the costs are higher, or gross value less, than could be obtained in the actual conditions of the real world, that is the basis for criticism.

Considerations of equity and the interests of special groups, e.g. in small coastal communities, will, as discussed in the next section, often require a fishing policy in which the efficiency in pure economic terms is reduced. At least in the short term the same is true for stocks that are extremely vulnerable to biological over-fishing. Unless enough spawning salmon are permitted to proceed upstream, the subsequent run will be very small. The allowable catch could be taken very cheaply by a few efficient gears, e.g. traps operating at the mouth of each river. It would be very difficult to know which few persons should operate these gears and enjoy the enormous potential profits. It is politically and socially much easier to keep the fishing mortality down to biologically acceptable limits by allowing only the less efficient gear - and then only under strict, and efficiency - limiting controls on when and where they can be used. The costs of harvesting the North Pacific salmon may be much higher than the theoretical minimum, but on the criterion used here - of what could have happened if there were no controls - the management programme has been justified.

Salmon are somewhat of an exception. For many stocks the increase in total yield from restricting the amount of fishing is not large. There may be advantages in reduced year-to-year fluctuations in catch, and increased stability of the fish stock and the fishery. The greatest benefits from management will, however, come from the opportunities to reduce the total costs. Whether these can be realized as soon as regulations are introduced depends mostly on the timing of the management, rather than the specific measures introduced. If management is not introduced until the amount of fishing and the size of the fleet is too large, then it will be difficult to get immediate economic benefits. There will be great obstacles to preventing many of those already fishing to continue. In any case once excessive numbers of vessels have been bought there may be little opportunity for saving the capital costs by using them in other fisheries. The best that can be done may be to reduce some of the excessive running costs, e.g. by reducing the length of the open season, or requiring vessels to stay in port for several days between trips.

On the other hand, if measures are introduced while the fishery is expanding towards the optimum size, it is much easier to realize the economic benefits even in the short term. In addition the actual implementation of the measures will be much easier, since they will mostly be concerned with preventing new entry to the fishery, rather than removal of those already in the fishery. Direct control of the amount of fishing or fiscal measures are likely to be more successful in deterring the hold-up of excess effort than controls of catch. Depending on how catch controls are applied, they may actually encourage the growth of excess capacity as individual fishermen or fishing enterprises try to maximize their share of the total catch.

The differences in the abilities of various management systems to maintain or increase economic efficiency become most obvious after the controls on the amount of fishing have been in operation for some time. Here there is a potential conflict between biological and economic considerations. The latter will usually require that the fishing mortality (i.e. the actual impact on the stock) remains about the same from year to year. Improvements on economic performance, however, will usually lead to increases in the fishing mortality exerted by an individual boat, or by a fleet of a given size. A distinction should be made here between changes in performance that are real economic improvements (e.g. from the development of an improved piece of gear), and changes that are basically intended to get round the regulations, or at least to take full advantage of them. A common example of the latter concerns the size of ship. Controls on fishing effort may take the form of allowing a certain number of ships to operate; the fishermen then respond by replacing their ships by bigger ships; controls on the length of vessel result in ships with greater beam and tonnage; controls on tonnage by larger engines, and so on. These changes will allow those fishermen who are first to make them to increase their share of the total catch. However, this increased share involves increased costs. The economic efficiency of the individual vessel will not increase much, while that of the fleet as a whole will decrease, at least until steps are taken to reduce the number of vessels appropriately. These latter changes should therefore be discouraged.

The first type of change - in real economic efficiency - should normally be encouraged. The exception would be the salmon type of situation where increased fishing mortality would lead to a substantial drop in catch, and where there are great practical difficulties to keeping the fishing mortality in bounds if the most efficient gears are allowed to operate. The management scheme should therefore normally allow such developments, but it must also do so without allowing the fishing mortality to rise above the desired level. Here it might be noted that, since fishermen are more cunning than administrators, there will (however the regulations are framed) usually also be changes in fishing power of the second type. These too need to be allowed for in the regulations. For catch quotas there is no problem, but for effort limits this will mean that, say, the number of vessels licenced to fish will have to be progressively reduced. The extent and frequency of the adjustments will vary from fishery to fishery. They are likely to be less frequent than the generally annual adjustments to catch quotas, but will require continuous and careful monitoring of the practices of the fleet. This should in any case be done as part of the work involved in monitoring the fishery, especially for the interpretation of catch and effort data.

Different management practices can also affect the economic performance by their impact on the value of the fish. The price of fish will be relatively high if the supply to the market is regular and predictable, and when the fish are landed at seasons when quality is good or demand high. The choice of management measures can affect all this. In principle catch quotas, if allocated to individual enterprises, will allow the supply of fish to be known well in advance, and marketed to the demand. In practice, catch quotas have often not been allocated. This has usually led to a flood of catches at the beginning of the open season, as fishermen try to maximize their individual catches. Controls on fishing effort, e.g. vessel licences, seem less likely in themselves to affect the value of the catch. More important may be the manner in which the regulations are applied. Sudden changes may make it difficult for the industry to adjust and take advantage of the changes. This is particularly likely to happen when there is a long chain from the fisherman through processor and distributor to the ultimate consumer. Thus there have been occasions when a herring fishery has been suddenly opened for a short period and most of the catches have gone for fish meal because the much higher valued market for fresh fish or smoking was not geared up to deal with the unexpected volume.

Equity and distribution of benefits

Fisheries often receive an attention greater than that appropriate to their contribution to the national Gross Domestic Product because of their importance to small local communities, in which there may be little alternative employment. The success of management should therefore often be judged more by the impact on these groups of small-scale fishermen and others, than by the impact on the fisheries as a whole. These distributive effects can be immediate and usually obvious, or long-term and possibly subtle.

The immediate effects include the clearly discriminatory measures, such as the prohibition of certain types of gear (the recent banning of trawling throughout nearly all of Indonesia is the outstanding example), limits on the areas where different sizes of vessel or types of gear can be used, etc. Control of fishing effort, e.g. licensing of vessel or allocated catch quotas, may also permit direct discrimination in terms of who gets licences, or particular shares in the overall catch quota.

The long-term effects can vary with even quite small differences in the form of management. If management is by direct control of effort, and the restriction of the number of vessels that are licensed to fish, there will have to be some scheme for changing the licence holders as fishermen retire, or as the total number licensed has to be altered to adjust to the target fishing mortality. Economic efficiency might call for licences to be freely bought and sold. Such a free market may result in ownership of licences becoming concentrated, perhaps in a few big companies. If this is felt to be undesirable, then the system of transferring licences will have to be suitably designed.

Transaction costs

Good fishery management does not just happen. It has to be based on adequate research, an effective administrative machinery to determine the desired measures, and the ability to enforce these measures. All this takes money, and the amount of money involved is not the same for all types of measures. Research and enforcement are generally the most costly items, and also those where the volume of work involved is most susceptible to different management policies.

A fair volume of research will be necessary whatever management policy is adopted. The difference in research requirements occur when year-to-year adjustments have to be made.

Thus if regulation is done by catch quotas, the biomass in the coming season must be well enough known to be sure that the catch quota set will generate a fishing mortality within acceptable limits. The amount of research needed will depend inter alia on the life span of the fish, and the extent of natural variation (especially year-class variation) in the stock. For a long-lived and not very variable stock, acceptable estimates may be obtainable from the data on catch rates and age composition in the commercial fishery during the past year. These will normally be obtained as part of any programme of monitoring the stock without needing special research. For short-lived and variable stocks, it may be necessary to obtain estimates of the newly recruiting year-class through special -and usually expensive - research surveys. In contrast adjustment of effort controls requires little special research although an extensive amount of economic and social analysis may be involved on the information awaited from effort control. There are unlikely to be violent year-to-year changes in the effectiveness of a unit of effort (i.e. the catchability of the stock). More usually there will be a general upward trend as part of technological improvement, and this should be detected and measured as part of the normal research studies of the relation between stock abundance, catch and nominal effort.

So far as costs of enforcement are concerned, the most important factor is the degree to which enforcement can be carried out in port, or requires close checking of the fishing vessels at sea. This depends not only on the legal form of the regulation but the practical ways in which it may be evaded. Thus the mesh size of trawl nets can be readily checked in port, but the true compliance with a mesh regulation needs careful inspection at sea to check on the use of covers, double cod-ends or other ways of reducing the effective mesh size.

If only a single stock was concerned, many forms of effort control could be enforceable from shore. Problems arise when a fisherman can claim to have taken his catch from an unregulated stock or to be using his vessel in an unregulated fishery. Checking on this will require close control on what is actually happening at sea. This is also needed for some of the other detailed regulations, such as closures of specified small areas in order to minimize conflict between fisheries directed at different species to be shared at sea. The details to which measures of this kind are taken will probably depend on the extent that these can be enforced by equally detailed control, and on whether the costs of such detailed control are justified by the benefits achieved.

There are other less quantifiable transaction costs involved in different types of management. To the extent that research staff are involved in recurrent calculations of, for example, the allowable catches for several stocks for the coming season, they are not able to look at other matters. It seems probable that some of the failures to develop a long-range strategy for management of many fisheries, e.g. in the North-East Atlantic, has been because the scientists who could help develop such a strategy have been too busy with determining annual TACs. Again, in many fisheries, the way that management measures have been put into effect has meant that the system has resulted in a set of conflicts - between different groups of fishermen, between scientist and administrator, and most seriously between administrators and the fishermen. Though a quantitative measure is difficult, the extent to which one or other particular approach to management can be implemented without excessive burdens on research staff, and without excessive arguments between different groups, should be an important criterion in the choice of approach.

THE INTERACTION BETWEEN FISHERIES MANAGEMENT AND THE MARKETING OF FISH

by

Iain MacSween
Scottish Fish Producers Organization
Edinburgh 4, Scotland

Abstract

The marketing of fish is an integral part of the activity of fishing. As such any management measures introduced have implications for the marketing of the species in question.

There are two basic categories of objectives of management - biological and economic. The biological objectives, is based on the idea of maximising physical yield, although this is a rather simplistic objective and one that is difficult to attain and measure. The economic objective comes into conflict with the biological one when it is argued that the emphasis should be on the economic yield, not the physical yield. But if maximum sustainable yield is too simplistic, then economic yield can be criticised as too complex given the inter-relationship between costs and prices.

The actual objectives, therefore, inevitably involve some compromise, particularly internationally when added complications arise. This compromise tends to lean towards biological yield and in particular to the introduction of catch quotas.

Given that catch quotas are to be introduced they can affect either the size, the condition, and the total amount of fish caught.

The marketing of fish tends to have been ignored by managers and as it is part of an interrelated process it must be taken into account when desiring management measures. But there may be conflict between the needs of management and the needs of the market. Measures introduced may disrupt the flow of supply to the market throughout the year; they may also dictate the size and quality of the fish and these may not correspond with the standards of the market. Thus the product being delivered to the market can be affected by the management measures introduced.

In practice it has to be recognized that there are limits upon the volume a market can absorb. Achieving maximum physical yield could, therefore, cause serious marketing problems. Whilst oversupplying a market can cause problems, so can prohibiting fishing until a spawning stock biomass sufficient to sustain maximum yield is achieved.

The actual management measures introduced over the past few years within the European Community have tended towards those regulating the size of fish caught, the seasons and areas in which they can be caught and the total amount that may be caught.

Closures by areas or seasons generally cause no marketing problems and contribute towards stock conservation. This is particularly true if alternative supplies of the same species are available elsewhere, although closed areas can disrupt the supplies of other species contained within that area.

Regulations involving minimum mesh sizes tend to harmonize with the requirements of the market. Such measures generally result in the larger sizes being landed although it may on occasions lead to a shortage of some smaller fish.

Restrictive licensing has rarely been used and in the context of over-capacity has had no real impact on the market.

A much more common method has been restriction by per man or per vessel quotas. This can lead to cases of shortages or gluts and a deterioration of quality if there is not adequate on-board storage capacity. Fishermen will also try to land the very best quality fish and discard the remainder. In addition to undoing the benefits of conservation measures such practices deprive the market of the full range of selections.

INTRODUCTION

Fishing as an activity takes place when a number of conditions have been fulfilled. Broadly speaking these conditions are, when there is fish available to be caught and their existence is known; when fishermen and fishing vessels are available and able to exploit the fish stocks; and when some sort of market exists, prepared to accept the catches landed at a return to the catcher that makes future catching worthwhile.

Given this the state of a fishery can be judged in a number of ways. These include the volume of landings, the state of the stock or stocks which produce the landings, the level of profitability or otherwise of the vessels pursuing the fishery, and the returns enjoyed by the other sections of the industry. It follows, therefore, that the existence of more than one way of gauging the success of a fishery means that its relative state will be different according to the standpoint from which it is judged.

Nevertheless, it should be possible to find some situations which form an acceptable compromise from the point of view of most of the people involved. It is doubtful, however, whether such compromise solutions occur naturally, or if they do, whether they can continue in existence for very long. Indeed in several well documented cases a state of affairs has been reached in which the fishery is in an unhealthy state from all viewpoints. The most extreme of these is the case of those fisheries which have been prosecuted to the point of commercial extinction at least for a period of time. It has become increasingly obvious, therefore, that a laissez-faire policy cannot be relied upon to ensure successful and healthy fisheries, and consequently some form of fisheries management is generally necessary.

The conclusion that the management of fish stocks is generally necessary at some stage does, however, raise the question as to what exactly it should try to achieve. Broadly speaking the objectives of fisheries management as either implemented or suggested fall into two categories - biological and economic.

BIOLOGICAL OBJECTIVES

Fish are a living resource, capable of reproduction, and good management allied to certain stable external conditions can result in a stock being sustained for an indefinite period. Each stock is capable of sustaining a certain yield, and in the absence of fishing a stock of fish seeks to achieve equilibrium between the recruitment of young fish and the growth of existing individuals on the one hand, and the losses due to natural death on the other. When fishing commences, however, it will tend to reduce the size of the fish stock. This is in turn likely to be offset by an increase in recruitment and growth and a reduction in the number of natural deaths as a result, for example, of the increased food supply available to each fish. The fish stock may, therefore, achieve a new equilibrium position at which the rate of decrease as a result of fishing will equal the rate of increase through natural growth. This represents a sustainable yield and the size of this yield depends on the size of the fish stock. One such stock level is capable of producing the maximum sustainable yield which corresponds to the greatest physical yield that stock can produce and go on producing year after year. This concept was developed against the background of the law of diminishing returns applying to fish stocks and does, therefore, when converted into biological curves of yield against effort, produce a pronounced maximum.

So the biological approach has been to maximise the physical production of the oceans. Such an approach has several attractions. It suggests the production of the maximum possible foodstuffs and it is based on a fairly simple and understandable mechanism of how stocks react to exploitation. Another major advantage is that it is determined by a simple physical measure - the weight of fish actually landed and recorded. Not only does this assist in implementing the necessary management measures, but it removes the problems of differing relative values encountered in those fisheries exploited by different countries. But in reality the situation is not always so straightforward. Fish stocks do not behave in simple, mechanistic ways that can be accurately forecast and it is not always easy to determine precisely where the maximum sustainable yield occurs. This difficulty is compounded by the fact that the yield for some demersal species is flat over a substantial range in the vicinity of maximum yield. Furthermore the concept has been criticised on the grounds that it has nothing to say about the development of a virgin stock as it is not a dynamic concept - it specifies only the final

state, not the way in which that state is reached. Furthermore it is recognized that there are problems in maximizing the sustainable yields in mixed or multi-species fisheries, especially if some of the species are ecologically related, as when competing for the same food.

These difficulties are formidable enough, but the objective of maximizing the sustainable yield of a fish stock has also been attacked on economic grounds. This brings us to a consideration of economic objectives for fisheries management.

ECONOMIC OBJECTIVES

Economists have argued that the attainment of the maximum physical yield makes no economic sense, and that the goal of fisheries management should be to achieve the maximum economic yield. This is achieved when the difference between the total revenue accruing to a fleet participating in a fishery and the total costs of that fleet is at its greatest. This is, therefore, the profit maximizing position which is characterized in economic models by the equality of marginal revenue and marginal cost.

In most fisheries it is correct to assume that the maximum economic yield and maximum sustainable yield are achieved at different levels of fishing effort and that generally the maximum economic yield requires a smaller amount of effort than the maximum sustainable yield.

Maximum economic yield is not, however, free from criticism. One of its disadvantages is that some of the crucial inputs are the price of fish and the unit cost of fishing. Not only will these vary from year to year, they will almost certainly vary from country to country. Given the differing inter-relationships between costs and prices, it may well be impossible to determine a single maximum economic yield for all countries.

Maximum economic yield also has different implications from maximum sustainable yield, insofar as actual policy measures are concerned. Given that the level of effort associated with maximizing the economic yield is usually smaller than that associated with maximizing the physical yield, the adoption of economic yield could result in high unemployment in remote areas where there is little alternative employment.

Despite the difficulties associated with the attainment of maximum economic yield, the concept does nevertheless suggest certain policy measures. The recognition that the level of inputs devoted to an open access fishery is greater than that required for the economic optimum has led to the policy prescription that entry to the fishery should be controlled. More specifically it has been asserted that the goal of economic efficiency can be approached by preventing excessive entry into the fishery.

ANNUAL OBJECTIVES

Given that the policy maker is faced with a choice of objectives, it is clear that all the various interests are unlikely to be satisfied simultaneously at any one particular level of fishing effort. It is highly likely, therefore, that the policy adopted will seek to achieve some sort of compromise between the interests involved. This is particularly difficult in the case of international fisheries and especially because the different countries involved are likely to have different costs and earnings relationships and will give different weightings to the various objectives. Because of these difficulties and because non-biological objectives are rarely quantified, the biological concept of maximum sustainable yield has become the more widely accepted policy goal. The strategy of trying to achieve this yield is, however, modified in practice in the case of heavily over-exploited fisheries by the realisation that a rapid reduction from high levels of catches to a level commensurate with the achievement of maximum sustainable yield would be extremely disruptive in the short term. So whilst the long term objective of fisheries management is usually expressed as the attainment of maximum sustainable yield, the short term objective is usually expressed as some percentage change from the current level of fishing activity. To the fisheries scientist the level of fishing activity means the level of fishing mortality on the fish stock and the short term objective of management is, therefore, usually expressed as some level of fishing mortality.

Obviously, from the point of view of actual management measures, the concept of fishing mortality has to be translated into something more concrete and readily attainable and enforceable. The choice this presents is to either limit the level of fishing effort or to limit the overall catch, or sometimes a combination of both. In most international fisheries, but also frequently in domestic fisheries, the fisheries administrators have tended to favour catch quotas. Thus the advice which the administrators require from the fisheries scientists is usually the level of catch corresponding to some chosen level of fishing mortality. This level of catch is usually referred to as the total allowable catch and is the maximum total catch that can be taken from a stock by everyone fishing it in any one year to meet a specified management objective. This step by step approach towards a long term goal is also favoured because of uncertainty surrounding the impact on the ecosystems of major changes in the abundance of several of the main fish stocks in the system.

In the context of the European Economic Community, the basis for fisheries management is the sub-division of the total allowable catches for the various species between the individual Member States. Basically this continues the system established under the North-East Atlantic Fisheries Commission with the major difference that the extended jurisdiction of the individual littoral States creates a European pond from which non-Community countries can be legally excluded. So in some respects the policy prescription suggested by the proponents of maximizing the economic yield have been moved forwards as a result of the global movement towards extended fisheries jurisdiction. But apart from excluding all or part of the fishing effort of foreign countries, the main thrust of fisheries management has been devoted towards regulating the catches of particular species by a variety of methods.

TECHNIQUES OF MANAGEMENT

Over the years, a variety of management measures have been introduced and the principal measures have been as follows:

(a) The establishment of open or closed seasons

(b) The establishment of open or closed areas

(c) The regulation of mesh sizes in fishing nets

(d) The regulation of the size limits of fish that may be retained on board any fishing vessel, or landed and subsequently offered for sale

(e) The prohibition of directed fishing for particular species

(f) The regulation of the total catch of a species or group of species by means of "per vessel" or "per man" quotas

(g) The regulation of the number of vessels permitted to prosecute a particular fishery

(h) The regulation of fishing gear and appliances other than the size of mesh

These measures can mostly be placed into one of two groups according to whether they affect the size or condition of fish caught, or the total amount of fishing.

MARKETING CONSIDERATIONS

At the very outset, the activity of fishing was defined as an interactive process between the stocks in the sea, the process of locating and catching them and the final stage of actually marketing the produce. In the literature and practice of fisheries management, however, consideration and action is usually confined to only two of the areas outlined above. The biological objectives of management relate to the state of the fish stock in question and many of the actual management measures taken are introduced with the specific objective of controlling the size and amount of fish removed from the sea. In a similar fashion the debate surrounding the economic objectives of management is concentrated primarily on controlling the level of fishing effort devoted to a particular stock. Very little consideration has been given to the impact of such management measures upon the marketing of the produce or indeed the implications for management of satisfying the marketing requirements in respect of the managed species. This has proved in some respects to have been a serious omission has has led to serious problems.

Given that the marketing of the catch is an integral part of the activity of fishing, it is essential that any management measures are devised with this in mind. There is very little point in managing a fishery in such a way that it leads to either a collapse of the market which will in turn preclude the catching of the fish or to a level of returns to the catcher that will render his operation unviable and lead to a cessation of catching in the longer term.

It should be recognized, however, that there are many difficulties in introducing and enforcing management measures which would simultaneously satisfy the requirements of preserving the stock, making the fishing operation viable, and satisfying the requirements of the market.

Indeed in some respects the needs of the market are at variance with the way in which fishing vessels operate. In the United Kingdom where most of the fish landed is subject to processing of some kind or another, the basic requirement of most processors is for an even and continuous supply of fish of an acceptable quality to ensure continuity of production in their processing factories. This is particularly true of demersal fisheries. Furthermore, the marketing infrastructure is generally geared towards dealing with a continuous inflow of fish that will maintain ports, cold storage and freezing facilities, transport facilities, processing and distribution facilities operating at a viable level. But for a variety of reasons, even in a situation in which there is no necessity for management measures, it is very difficult to ensure a smooth and continuous supply of fish to the market where this is desired. This may be the result of natural factors such as weather or changes in stock abundance which lead to peaks and troughs in the volume of supplies to the market. For example, fishing for demersal species in the North Sea tends to be frequently curtailed during the winter months due to adverse weather and the shorter number of daylight hours. Other species such as mackerel which are migratory by nature are only available to be caught in a relatively few months each year, and so landings reach a peak in those months with very little being caught in the remainder of the year.

Processors wishing to handle migratory species such as mackerel, and/or shellfish whose landings peak dramatically in the summer, must therefore resort to freezing stocks, to provide for continuity of production throughout those months in which there are little or no fresh supplies available.

But the market may require certain fish at specific times of the year when their quality reaches an acceptable standard. Herring is a prime example. The marketing of this species depends crucially upon the condition in which it is landed. Autumn spawning herring is in its prime condition in the summer months prior to spawning when its flesh tends to be full and firm, and the fat content acceptable for a variety of end products.

So the marketing requirements for some species is for a continuous flow of supply throughout the year, though this is likely to be disrupted from time to time by a variety of natural factors. In the case of certain other species, however, the marketing requirements are such that the fish are only acceptable at specific times of the year due to the variations in quality that occur naturally throughout the year.

Insofar as volume is concerned, the market also places demands upon the catcher as to the size of fish landed. So there is at the point of catching a direct inter-relationship between the size of fish the market requires, and the size of fish the scientists recommend be taken for conservation purposes. So although there may be no direct marketing input into the management process, some management measures do in themselves dictate the nature of the product delivered to the market, and ideally that which is delivered should correspond to that required by the market. Equally the market sets standards for fish insofar as the presentation and quality of the product is concerned. These standards can be crucially influenced by the management measures adopted. Quality is obviously affected by the handling practices on board the catching vessel, such as boxing and icing, and by the length of time the vessel remains at sea. Management measures which try to influence the level of fishing effort can, therefore, indirectly affect the quality of the fish landed. This can work in either a positive or a negative manner. Measures which tend to shorten fishing voyages in an attempt to curtail the level of fishing effort would generally be expected to result in a better quality fish being landed. But management measures can also lead to longer fishing voyages on occasions and thus have a detrimental effect upon the quality of the fish subsequently landed. It is also possible for management measures to be devised in such a way that they affect the presentation of the fish brought to the market. In the case of demersal species, for example, management measures can be framed so as to require species

to be landed in a gutted as opposed to an ungutted condition. This has a fairly direct influence on the level of effort devoted to a fishery as the process of gutting tends to reduce the speed of the fishing operation, and it also reduces the choice of presentations laid before the market.

It would appear, therefore, that whilst the marketing requirements may be fairly specific insofar as volume, size, quality and presentation are concerned, these can be influenced not only by natural factors, but also by the impact management measures have upon the actual process of catching, and the subsequent delivery to the market.

Fluctuations in catches result also from the pattern of fishing adopted by the fishermen. In a Scottish context there is a tendency for a large part of the fleet to operate on a weekly basis with boats going off to sea on a Sunday evening or early Monday morning. Such vessels generally land towards the end of the week and in particular on Thursday and Friday. Such a pattern does not always correspond with the requirements of the market which would ideally wish to avoid an upsurge in landings towards the end of the week when demand for the product is generally tending to tail off. Management measures may similarly affect the pattern of fishing and thus affect the marketing regime. Measures designed to curtail the level of effort can lead to more frequent landings, whilst other measures, and in particular those curtailing the permitted catch, can either curtail or prolong fishing voyages, depending upon the rate of catch recorded by the vessel. So management measures which affect the pattern of fishing directly can also indirectly affect the marketing of the produce. One would hope that this effect would be beneficial in its impact.

It is obvious, therefore, that the measures adopted to manage fisheries have an influence on the marketing of the catch and it is important that efforts be made to coordinate any management measures with marketing requirements.

Given that the main thrust of fisheries management is the attainment of certain biological objectives, it is instructive to examine how these inter-relate with the requirements of the market and in particular how management measures actually adopted within the context of the United Kingdom's fishing industry have affected the marketing of fish.

The basic long-term biological objective of fisheries management has already been stated as the attainment of the stock's maximum sustainable yield. But from a marketing point of view it must be asked whether this is a desirable goal to aim at given certain limitations placed upon the marketing process in the short term. In this context it should be noted that the definition of market would primarily be outlets geared towards the provision of food for human consumption. For certain species the market can be radically expanded by utilizing processes to make animal foodstuffs.

Nevertheless it is important to establish that the market for a highly perishable foodstuff such as fish is finite. There are limits upon the volume that the market can absorb, either for human consumption or for other purposes. So whilst the biological objectives must of necessity be based upon the scientific assessment of what a stock can produce without adversely affecting that stock, attention should also be paid to what the requirements of the market are, and whether the level of fishing mortality associated with a particular total allowable catch is an appropriate target to aim at. The dilemma this poses is perhaps best illustrated by the position of North Sea herring and West of Scotland herring at the present time.

In the course of 1977 the North Sea was, on the basis of scientific advice, closed to directed herring fishing to prevent total stock failure. A similar decision was taken in 1978 in respect of the West of Scotland herring stock. The prohibition on the directed fishing of any species is the most extreme management measure that can be taken and its implementation poses a number of short and long term marketing problems.

The immediate short term result of any such closure is, of course, to deprive the market of supplies. Thus, from landings of just over 38,000 tons in 1977, the Scottish herring catch fell to 2,000 tons in 1979. The impact this has had on the market for herring was dramatic. Faced with the prospect of there being no fresh herring supplies available many of the smaller herring processors went out of business or switched to other species. This in turn deprived the consumers of supplies of a product to which they had become accustomed and which they had and purchased in substantial quantities.

This has had serious marketing repercussions in the longer term. In particular the non-availability of the species has led to a dramatic contraction of the market for the herring and its associated products. The problem this caused did not become immediately apparent to fishermen as they were able to switch their fishing activity to other species, particularly mackerel. The real scale of the problem only became apparent once herring fishing resumed in 1981 off the West Coast of Scotland. Out of a total Scottish catch of over 30,000 tons, some 11,000 tons remained unsold for human consumption and went for reduction to fishmeal. In the following year, of the Scottish catch of 30,000 tons of herring, some 8,000 tons had to be utilized for fishmeal. So in a very real sense, the ban on fishing for herring eliminated the demand for the species and caused very serious marketing problems. There were also some indirect effects. One of these was that those firms which remained in herring processing imported supplies from countries elsewhere in the world which continued to fish for the species. Having established chains of supplies these processors proved reluctant to dispense with their external suppliers even after domestic fishing had resumed.

So the most extreme management measure which can be utilized to achieve the biological objective of sustaining a healthy stock is likely to have extremely serious repercussions for the marketing of the species in question. Any prohibition should, therefore, only be introduced in those circumstances in which continued fishing is likely to result in stock failure.

The markets for the produce of the sea are finite and consideration should therefore be given to whether the attainment of maximum sustainable yield is the best objective. From a marketing point of view should not policy measures aim at an alternative objective? Again the problems this can pose can be examined in relation to herring. The estimated maximum sustainable yield for North Sea herring is put somewhere in the region of 600,000 tons per annum. The comparable figure for the West Coast of Scotland is in the region of 100,000 tons. So the possible herring offtake from the European pond would, if maximum sustainable yield was achieved, be in the region of 700,000 tons per annum, without taking account of any additional supplies from the Baltic or the more northerly Atlanto-Scandian herring stock. This volume is certainly in excess of market requirements insofar as human consumption is concerned and does, therefore, raise the question as to the time scale that should be pursued in moving towards the long term biological objective. In the case of the North Sea, the scientific advice has been that directed herring fishing should not resume until a spawning stock of 800,000 tons has been achieved. At this level it is considered that the risk of recruitment failure due to a low spawning stock biomass is relatively low. But is it realistic to defer a resumption of fishing till this level of spawning stock is achieved in the knowledge that the longer the resumption of fishing is delayed the less likely there is to be a market for the produce, unless of course, fishmeal is considered to be an acceptable outlet? There is surely a very real case for allowing fishing on over-exploited stocks even if this delays the achievement of the long-term biological objectives, if the alternative is the disappearance of the market for the species involved. Such a decision should not, however, be taken if this involves a real threat to the future of the stock and this, therefore, implies more stringent management measures than might otherwise apply.

It can be shown, therefore, that there could in certain circumstances be an element of conflict between the requirements of the market and the biological objectives of management, and this should be borne in mind when devising actual management measures.

It is also possible for such conflict to be present in those situations in which a fishery is being managed to attain the so-called economic objective. Accepting the general premise that the maximization of the rent of a fishery involves a level of fishing effort less than that associated with maximum sustainable yield leads to the conclusion that the level of catch actually taken will be somewhat less than the maximum physical yield possible. But in the case of many species the level of catches associated with maximum sustainable yield is not excessive in relation to market requirements. This is true of many demersal species such as cod in a European context. Even if maximum sustainable yield of cod was achieved in the waters of the European pond there would still be a shortfall compared with the level of supplies required by the market. To manage such a fishery on the basis of economic objectives, and restrict the catch even further, would therefore deprive the market of supplies which could be absorbed without depressing returns to the catchers to uneconomic levels. This would result in a market disequilibrium if alternative supplies could not be found elsewhere.

So, there can be a degree of conflict between the marketing requirements for a particular species and the general objectives of fisheries management, whether these objectives be biological or economic. It is therefore not sufficient when considering the management of a fishery to consider only the objectives of that management. Consideration must also be given to the implications of the management regime introduced and in particular how they affect the marketing of the produce, which activity is as important as actually catching the fish.

IMPACT OF MANAGEMENT TECHNIQUES

Having established that it is possible for the requirements of the market to be at variance with the objectives of management, it is instructive to review the interaction between those management measures generally adopted and the needs of the market.

Open or closed seasons and areas

Closed seasons have normally been introduced to protect mature fish prior to and during spawning. This measure is frequently combined with the closure of a specific area which is known to correspond to the spawning grounds of the species in question. Closed seasons have often been adopted in the case of pelagic species when their spawning is somewhat concentrated geographically and chronologically. Given this the impact on marketing may be minimal as the quality of pelagic species tends to be better just prior to spawning. Marketing problems in this sphere have also been avoided due to the fact that several pelagic fisheries may be being prosecuted concurrently. So the closure of the West of Scotland herring grounds in late July and August was offset by the prosecution of herring fisheries in the Firth of Clyde, North Sea and North Irish Sea. Thus the impact of areal or seasonal closures on the market will be minimized if there are alternative supplies and this has often been the case insofar as pelagic species are concerned.

In recent years, however, there has been a move towards areal closures to protect the younger fish contained within a stock. The British Government has for several winter months each year closed a specific area on the West Coast of Scotland where it is generally accepted that young herring over-winter. As young herring are of little interest to the market such a closure is actually beneficial. It prevents supplies that are unwanted coming on to the market. Much the same is true of mackerel in the waters off the South-West of England, where it is known that one of the stocks over-winters. A high proportion of these fish tend to be young and not in demand so the prohibition on fishing within the designated areas helps both to conserve the stock and to prevent supplies of undesirable sizes of the species coming on to the market. One problem with such closures is that they can lead to problems in supplying the market with other species that may be located in the closed area. An example of this is the sprat fishery off the West Coast of Scotland. This fishery was normally conducted in areas and during a period in which it is now prohibited to fish by the only means of ensuring the capture of the sprats, namely pair trawling. As pair trawling was a chief means of catching herring, it was decided to close the fishery by prohibiting this type of fishing. So one side effect of a measure designed to protect herring has been the virtual closure of a sprat fishery. Much the same has also taken place off the South-West of England where there has been an areal prohibition on the catching of mackerel via prohibition on the means of capture. In this case the species that have been denied to a market which exists to accept them have been pilchards and horse mackerel.

So closures whether by area or by season may have generally beneficial effects from a marketing point of view but may on occasion lead to the market being deprived of other species.

Mesh size, minimum landing size and prohibition on gear

One of the earliest measures to conserve fish stocks was the introduction of legislation regarding the permitted minimum mesh sizes of nets. Again such measures are generally beneficial from a marketing point of view in that they are usually associated with a minimum landing size per species. As the market for fish has developed, there has been a gradual move towards a preference for the larger sizes landed. In the United Kingdom this reflects the fact that most of the fish landed is processed in some way before it reaches the consumer. At its most basic this processing takes the form of filleting. Fillets need to be of an acceptable size and this has led to there being very little

demand for fish below a certain size. There has been harmonization between the legal landing sizes and the sizes required by the market and to that extent the measures have been compatible.

Care must, however, be taken that mesh sizes do not increase to such an extent that particular sizes of a species are no longer landed. British vessels operating in the Norwegian sector of the North Sea are presently utilizing nets with meshes 15 to 20 percent bigger than in the remainder of the North Sea. One of the noticeable effects of this has been the marked reduction in the smaller sizes landed. Whilst this may be no bad thing from a conservation point of view, one of the growth areas in the market in recent years has been in the demand for quick frozen individual fillets which calls for smaller sizes of fish. These sizes have been virtually absent from the catches of vessels using the bigger mesh nets.

One of the areas of contention with regards to mesh sizes and gear in the British industry in recent years has been the shellfish sector. Scientific advice led to the adoption of 35 mm mesh nets for shrimps (Pandulus borealis) and the outcome has been the virtual disappearance of the North Sea shrimp fishery for whose catches there once existed a buoyant market. In the prawn (Nephrops norvegicus) fishery there has been much debate surrounding the use of 'lifters' or strengthening bags to lift the cod end. Vessels fishing for Nephrops are permitted to use a 70 mm cod end mesh as opposed to the 80 mm required for finfish. A by-catch was introduced for the Nephrops boats so that no more than half their catch by weight could consist of finfish. This has in all probability led to an increase in the volume of fish being discarded for which a ready market exists, but it does demonstrate the difficulties of not only making management measures compatible with the markets' requirements, and with each other, when one type of fishing activity infringes upon another.

Restriction on fishing vessel entry

In recent years there has been only one fishery in which the British Government introduced a system of restrictive licensing. This was the Isle of Man herring fishery and the size of the permitted offtake was such that the vessels granted licences were easily able to catch the total allowable catch in a way suitable to the market. The only other restriction on vessels implemented in the United Kingdom was a ceiling on the number of purse seiners and freezer trawlers permitted to fish for herring and mackerel. As this restriction was introduced to prevent any additional catching power from joining the fleet, it did not deprive the existing vessels in these categories from pursuing the fisheries they chose. Again there was not a discernible impact on the marketing of the species involved.

Restriction by per man or per vessel quotas

One of the main means of managing fisheries in the United Kingdom has been through the "per man" or more lately the "per vessel" quota. The concept of the per man quota has been traditional in the Scottish fleet and reflects the fact that the method of crew remuneration was and indeed is based on a share system. Under the system the crew are allocated a share of the vessel's gross earnings and this is then divided equally amongst the crew members. It was perhaps natural, therefore, that the early attempts at management which were voluntarily introduced by the herring fishermen themselves should reflect the practices of the day. The per man system attempted to achieve an equitable result for all those prosecuting the fishery. It was also thought that, once the requirements of the market could be ascertained, management would become a matter of dividing the requirements of the market by the number of fishermen participating in the fishery. Thus not only was the system thought to be equitable to those participating in the fishery, but it could be utilized as a means of ensuring that the supply delivered to the market was broadly in line with the level of demand prevailing.

In more recent years this approach has been adopted by the Government in its attempt to manage various fisheries such as herring, mackerel and haddock. In the case of mackerel, to facilitate enforcement the quota is now fixed on a per vessel basis. Another change in the recent past has been the introduction of fortnightly quotas for mackerel. This was specifically introduced to overcome some of the marketing problems that had become apparent in the operation of the weekly quota system.

Although the implementation of a per man or per vessel quota enables the market's requirements to be met provided they are known, it can result in temporary surpluses or shortages. Fixing the quota in terms of a period of a week may result in the market being over or under supplied. If, for example, many of the vessels participating in the fishery are successful in catching their permitted quota in the early part of the week, this can result in a temporary over-supply situation. And the converse of this is that towards the end of the week or quota period the market tends to be under-supplied.

Apart from this, one of the potential problems of a weekly quota system is that it may actively discriminate against certain markets. It was well known to Scottish fishermen that there was a ready market for their mackerel catches in Denmark, but the size of the weekly quota was such that it was barely viable for vessels to take their quota to the Danish market. Accepting that the problem could not be overcome by merely increasing the permitted weekly quota, the solution adopted was to introduce a system whereby a vessel could in any one week land up to two week's quota provided, of course, that no fishing took place in the remainder of the quota period. Thus by amending the quota system it was possible to exploit a new market. But even this system had inherent in it some potential difficulties and especially the difficulties that would result for the market if most of the vessels were able to catch their permitted double quota in the early part of the first week of the quota period. This would result in a glut in the early part of the quota period with some fish remaining unsold followed by a severe shortage in the latter part of the quota period. A possible solution is to divide the catching fleet into two sectors, permitting one to commence fishing a week earlier than the other. This system was used with some success in the summer herring fishery off the West Coast of Scotland this year.

The type of pulse fishing these management measures encourages has implications for the marketing of the catch. Catching a week's or two week's quota in one night obviously raises the question of qualitiy and acceptability if a vessel has to wait several days before discharging the catch. The fact that a weekly quota system for herring and mackerel and a two-weekly quota system for mackerel can exist without adversely affecting the quality of the fish is a reflection of the fleet's investment in means of preserving their catches. All of the Scottish purse seine vessels that pursue herring or mackerel are now fitted with either chilled or refrigerated seawater tanks that enable them to retain the fish on board without the quality deteriorating. To remain viable without destroying the stocks the vessels had to catch their quotas in the shortest possible time. But to ensure that their fish could be sold, substantial investment in on-board freezing was necessary. This in turn made the operation of a two-weekly quota system possible. A further development of this might be a sectoral system whereby vessels are allocated a quota for the entire fishery in advance of the fishery. The marketing problems inherent in such a system are, however, obvious.

The per man or per vessel quota systems create problems for fishing vessels without adequate on-board storage capacity. Vessels which have traditionally boxed and iced their herring and mackerel on board have been faced with the prospect of there being alternative better quality supplies available. And as these are primarily summer fisheries, unless a quick discharge can be obtained, then it is unlikely that the fish will meet the necessary quality specifications.

In the case of demersal species such as haddock which have been managed on a per-man per-week basis, there is no comparable difference between quality as all such fish is boxed and iced on board the fishing vessel. Nevertheless, some of the same problems that emerged in the pelagic fisheries have occurred, resulting in an uneven supply of the species to the market. When fish is to be found many vessels are likely to take their quota in the first few days of the quota period, causing shortages in the latter part. This outcome does at least have a beneficial impact on quality as the fish is landed within a few days of capture and unless the market is grossly over-supplied, can be spread over a few days by the processors. But if fish is scarce, then small quantities of fish tend to be landed in the early part of the quota period and surpluses develop towards the end of the period. In the context of the Scottish fleet this exacerbates the problems arising from the traditional weekly pattern of operation. A situation in which vessels have to stay at sea longer in order to catch their quotas also has a detrimental effect on the quality of the fish subsequently landed.

Faced with a quota which restricts the volume of a species a boat can land, the fishermen may make decisions that affect the total marketing picture. Given a limit on the volume of landings, the fishermen will attempt to maximize their revenue by landing the best possible selection and quality of fish. So the best quality will be retained for supply to the market and selections that are thought to be in greatest demand will be retained at the expense of less sought-after species. In most instances this means that the larger fish will be retained and the smaller sizes discarded. This can have a beneficial effect on the market in providing more of the most sought after selections, but may on occasions lead to a scarcity of the smaller sizes. Such practices have implications for the conservation regime whose goals are hardly likely to be achieved if fishermen are continually discarding a high proportion of their catches in order to land a quota of the most sought-after selections.

One of the perverse effects of such a quota is that it may in some circumstances actually increase the level of fishing effort. Quotas are generally established in such a way that they restrict the activities of only part of the fleet. Other vessels will be landing catches below the quotas introduced, but one of the noticeable effects of quotas in recent years is that the vessels which, in a free fishing situation, are landing less than the quota actually increase the level of their fishing effort in an attempt to secure landings equivalent to the quota.

SUMMARY

The majority of the fisheries exploited by the industrialized countries in the northern hemisphere are either fully or over-exploited at the present time. It is therefore necessary that effective fisheries management measures be introduced. But in framing such measures one should bear in mind that marketing is an integral part of the activity of fishing. It must also be recognized that the objectives of management, whether defined as biological or economic, may on occasion be at variance with the requirements of the market. Management measures can have adverse or beneficial effects on the marketing of catches depending upon the circumstances prevailing within the fishery. In general, however, many of the measures introduced and in particular those relating to size of fish landed, have been beneficial to the market. The impact of other measures such as catch quotas is not so certain as they can have a disruptive influence on the market.

Given the complexity of the relationship between management and marketing, it is necessary to consider the implications of managing each stock in relation to the market for that species, taking account of the various circumstances prevalent at that time.

FISHERMEN AND FISHERIES MANAGEMENT

by

David B. Thomson
Farmhouse, Baberton
Edinburgh EH 14, Scotland

Abstract

This paper deals with the attitudes and responses of fishermen and fishing communities to fishery regulation measures. Any means used by Government to control, limit or direct fish-capture activities must necessarily affect the fisherman. His cooperation is essential to the success of the legislation. His attitude and reaction largely determine how workable any regulation will be in practice.

Fishermen tend to be individualistic and independent beings. This fact should not blind us to the enormous amount of cooperation that goes on within the industry, particularly within each port or community. To an outsider fishermen's behaviour may appear to be perverse or eccentric at times but it is little different in essence from that of any group or society whose livelihood, way of life, or existence is under threat.

The reaction of fishermen is viewed from the background of his profession and way of life. It is examined in two main areas: observation or infringement of regulations, and general communication with Government on the subject of fisheries management.

The specific purpose of management measures is then discussed and the situation facing fishery managers summarized. Some aspects of well-developed fisheries in industrialized countries are treated separately from fisheries in developing parts of the world as their situations are quite different and may merit different management goals and measures.

Ways of improving fisheries management and avoiding pitfalls are suggested in the concluding section. The importance of fostering good relations with fishermen and of involving them in the decision-making process is emphasized.

1. FISHERMEN'S ATTITUDES AND VALUES

1.1 Fishing Communities

The vast majority of fishermen live in towns or villages where fishing is the major single industry. Those residing in larger towns or cities tend to live in an enclave or section of the town close to the harbour. Within those tightly knit communities there exists a camaraderie and a set of values different from those of non-fishing communities. The prestige figures in town are the top fishermen. The daily gossip invariably centres around the fluctuating fortunes of the fishery. Fishermen's wives identify with each other both in the weekly fluctuation of their husbands' earnings and in the way they must assume more responsibility in the home when their husbands are at sea. In both these respects their lot differs from that of most shore-workers' wives. In some countries the wives are active in the processing and marketing of the fish catch.

While the fishing industry can and does accept small numbers of total newcomers, most new entrants come from a fishing family, or at least from within the fishing community. By the time a boy steps on board a vessel as a crew member proper, he has already absorbed years of folklore and peer pressure that have conditioned his outlook. He becomes a fisherman not just for the sake of earning money, but to commence a life career - and not just a life career, but for him the only logical career in life. Thereafter his experiences and companionships within the industry will further cement him into the fishing fraternity.

For a fisherman like that to leave the industry is a traumatic step, rather like denying the faith. Most traditional fishermen will leave the sea only if obliged to do so by reasons of ill health or severe economic hardship. Their natural commitment to fishing is beyond doubt. They are not "fair weather birds". In affluent countries the characteristic is less pronounced but most fishermen have this social and cultural attachment to their profession.

1.2 Fishermen as Hunters

Fishermen are hunters, members of the last remaining world-wide profession that involves pursuit and capture of its prey. Their whole training is geared towards maximising fish catch by every means possible. To this end, wits, stamina, intuition, experience are all applied. Risks to life and limb which would be unacceptable in any land-based job are faced regularly in the pursuit of fish. The fisherman battles with the elements, with the elusiveness of the fish, and in the face of severe competition at sea, to bring home his catch.

Any obstacle put in the way of a fisherman is instinctively seen by him as a challenge. He will use all his shrewdness and resourcefulness to get around it. This attitude must be faced by those attempting to regulate fishing by legislation. If the particular regulation has a loop-hole, the fisherman will find it.

1.3 Moral values and social acceptance

If a particular measure does not meet with the fisherman's sympathy (albeit grudging) then it stands little chance of effectiveness. Many communities of fisherman are extremely moral and demand high standards from all their members. But these standards may be based on subjective judgements, particularly in the case of fishery laws. Should the fishermen feel that a law has no moral basis or that it is not effective in achieving its objectives, then they will tolerate or sympathize with infringements by their fellows. Conversely a fisherman breaking a regulation that has widespread support will have to endure the opprobrium of his community, and that is something no fisherman can afford to ignore for long.

1.4 Remuneration systems

Most fishermen's earnings the world over are based wholly or partly on a percentage of net vessel earnings. Their income is directly related to their productivity. Even in fisheries where earnings are consistently low, the possibility of larger share-outs from a bumper catch is a constant spur to greater effort. Experience has shown that as soon as this element is withdrawn from the remuneration agreement, the fishermen begin to work to rule and are disinclined to take risks. Some basic wage security is sought in fisheries with a history of exploitation, or in newly developed fisheries, and there a basic wage plus bonus system may prevail. In better developed and more prosperous fisheries there is usually no basic wage and earnings or shares are a complete percentage of net vessel incomes. As a rule, company-owned vessels operate a wage and bonus system and fisherman-owned vessels work a share system.

This is mentioned to emphasize the need for keeping the prospect of higher earnings before fishermen, to maintain incentive and productivity. An over-regulated fishery could discourage enterprise to the point where the total rent from the industry becomes uneconomic. A prosperous and productive catching sector can create and support prosperous marketing, processing and ancillary industries. But a half-hearted fishing effort will stimulate little industry ashore.

2. CONFLICTS, COMPETITION AND COOPERATION

2.1 Competition and Cooperation

Fishing is a competitive business. At sea fishermen compete with each other over limited fishing grounds and limited fish stocks. Ashore they vie with each other to obtain the best price for their catches and sometimes just for the sale of their catch on a limited market. The competition is seen in the way fishermen may withhold from one another, information about their fishing grounds or about their gear and techniques.

Despite the competition there also exists a strong element of cooperation, especially between fishermen from one particular port or village. They cooperate with each other at sea in matters of safety and to a lesser extent with fishing information. Ashore they may jointly purchase and share facilities for marketing fish and servicing their vessels.

Conflicts between fishermen are more likely to occur between distant communities than within any particular community. It is not that frictions are absent within localities but rather that the degree of closeness and the existing cooperation make it easier to resolve disputes. Conflicts between distant groups of fishermen are difficult to resolve in many regions because of the lack of organized leadership. Often ad hoc committees are set up to deal with a problem and then disbanded immediately after.

Organized cooperation has taken many forms over the years and in different cultures. Looser associations are often preferred to cooperatives proper, but their functions are similar and relate to bulk purchase of supplies, aquisition and management of facilities, and marketing of fish. Some self-regulation of fishing activities may also be practised.

2.2 Self-regulation

Self-regulation of fishing activities has occurred from time to time in certain localities. Often it has broken down only after an influx of large numbers of vessels from outside the locality which were too numerous or too powerful for the locals to control. Self-regulation has taken many different forms and some are listed below.

Fishermen have agreed to observe non-fishing days and closed seasons for social as well as fishery reasons. The date for commencement of an annual fishery has often been agreed upon within a community. Some fishermen groups observe taboos or prohibitions on killing certain species. A common modern form of self-regulation is the scheduling of fish landings to avoid large gluts on the market at any one time.

2.3 Unregulated fisheries

Competition in an unregulated fishery assumes a new dimension when the total fishing capacity has increased past the point where returns per unit effort start to fall. Thereafter, any increase in effort tends to produce a 'dog eat dog' mentality in which only the fittest survive.

Under such conditions, survival instincts may result in two kinds of behaviour as regards capitalisation. The most common, particularly where money is available, is to invest in more powerful, better-equipped units to get the maximum technological advantage. The other reaction is to minimize expenses, particularly operational expenses, as far as possible so that despite falling catches the vessel or unit will not go into debt. Thus a fishing fleet with excessive catching capacity may tend to have a number of very efficient units and a large number of marginal vessels.

Local self-regulatory agreements break down when a fishery is under pressure and any moderation in harvesting the resource is discarded. There is a rush to grab as much of the stock as possible in a short time because of the expectation that it will be completely harvested well before the season's end. This is especially true for migratory or pelagic species which appear in abundance for a few months only.

Diversification may occur provided that underutilized species are to be found and that a market exists for them. This may relieve pressure on the main resource but is not in itself a permanent solution if total fleet catching power and effort are allowed to grow unchecked.

2.4 Equity considerations

Competition within any single fleet of vessels is liable to result in over-capitalization with individual vessels increasing in size, power and sophistication. This increase in catching capacity worries fishermen as well as governments. Fishermen who would be content with a unit of modest size are pressured to aquire larger or more powerful boats. The additional power is not really necessary to catch fish, it is needed rather to maintain catches in the face of the escalating competition.

Attempts to control this problem take the form of limits to length or tonnage within an overall limited entry or licensing programme. Unfortunately, neither length nor tonnage are directly related to fishing capacity. Vessels can be built beamier, deeper and with larger engines regardless of length or tonnage restrictions.

A much more meaningful and effective yardstick for determining fishing capacity is engine power. This can be measured as total engine power in maximum continuous brake horse power. Auxiliary power would have to be added to that from the main propulsion engine. A ceiling on engine power in each vessel of a given fleet would give every fisherman a fairer chance of earning a decent income and would prevent excessive earnings by some who were able to afford much larger and more powerful vessels. It would also make control of fishing effort that much easier.

2.5 Inshore/Offshore Conflicts

A common and rather naive belief is that small boats fish close to land and big vessels fish far offshore where better catches are to be found. Unfortunately the real situation is quite different. The inshore zone is by far the most productive in fish, area for area, and the productive offshore zone extends only to the edge of the continental shelf. Beyond that there is very little fishing activity apart from those for oceanic species like tuna.

In the absence of any regulatory discipline, fishermen will take the line of least resistance and try to obtain a catch on the closest and most productive grounds. If thereby they infringe on the livelihood of local small-boat fishermen, their attitude will be 'it is a pity but fishing is a competitive business'. Without the protection of enforceable law, small-scale fishermen will always be vulnerable to unfair competition from fleets of larger vessels.

The competition is unfair because the large vessel can fish much farther afield and in deeper waters. It can travel long distances and can cope with the weather offshore most of the time. The small inshore boat has distinct limitations as to distance, weather, and fishing grounds it can work.

The small-scale fisherman also represents the coastal community situated closest to the inshore fishing grounds. These communities are often small and the fishing industry however small it is may be the chief basic industry on which the village or town has been built. Destruction of the inshore fishing fleet may cause serious economic and social repercussions in such communities.

Exclusion from inshore grounds is a measure offshore fishermen may resent but can learn to live with and which would not seriously affect their productivity. For the small-boat fisherman on the other hand, unrestricted competition with larger vessels could ultimately bring about his extinction.

2.6 National/Foreign Conflicts

International fisheries conflicts have occurred for centuries but have tended to be periodic and localized. As distant water operations developed this century, they became more frequent and more prevalent. The establishment of 200 mile exclusive economic zones (EEZs) for the fisheries of most countries has been the most important single measure taken to cope with the problem.

But the 200-mile EEZ does not in itself remove all source of conflict. Foreign vessels are still permitted to fish within EEZ limits, under licence or under joint venture agreements. A 200-mile zone is a colossal area to police and for many countries adequate surveillance is too costly, so infringements may continue to occur.

From the national fishermen's point of view, two requirements are indispensable in any agreement to permit fishing by foreign vessels. Firstly, the limits of their licence as to vessel size and type, fish species, area to be fished, and quantity to be taken, must be acceptable to the local industry as a whole. Secondly, the method of policing and of enforcing the licence conditions must be seen to be effective.

If either of these two items are lacking to some degree then resentment and bitterness will result. This may occasionally flare up into violent incidents at sea, or may manifest itself in a refusal by national fishermen to obey local or national fishery regulations. Some governments have permitted foreign fishing within their EEZ's as a quid pro quo for other trading privileges. Sometimes the licence fee charged has been insufficient to cover even the cost of surveillance. Such agreements can generate only ill-will and hostility between national fishermen and their governments.

3. FISHERY REGULATIONS: PROLIFERATION, PURPOSE & PRIORITIES

3.1 Proliferation of regulations

Fishery administrators and scientists refer often to the enormously complex nature of fishery problems in multi-species fisheries with multi-purpose vessels. Fishermen for their part might be forgiven for expressing bewilderment at the array of management measures and proliferation of fisheries regulations.

A skipper-owner has to know and comply with marine transport regulations that govern navigation, vessel seaworthiness, safety equipment, radio communication and skipper certification. He must be aware of the rights of fishermen employees and the obligations their employers have to adhere to. The mesh sizes in the cod ends of his trawls have to conform to regulations for his area. At sea he must be aware of any limit lines or restricted areas, and of times or situations in which he may or may not use certain types of gear. On top of all this he may have to obey a quota limit on his catch of certain species of fish and/or a limit to the permissable by-catch. And these measures may change at short notice several times a year.

It was C.F. Hickling who, over 25 years ago in a memorandum on fisheries to the British Colonial Office, warned of unnecessary legislation on management. That of course was in the days when many tropical fisheries were relatively under-exploited. He advised that no management measures be taken unless there was substantial evidence that fishing activities were threatening stocks, and cautioned that if measures were taken, great care be exercised to ensure that the regulations devised really did solve the problem, were easily enforceable, and had no serious side effects.

Bad legislation or unnecessary legislation will always bring good legislation into disrepute. Unfortunately, in most developed fisheries, we are already in the situation where fishermen are bitter at politicians and legislators over what they consider to be unhelpful regulations.

Part of the blame may lie in the lack of communication or inadequate communication between fishermen and legislators. The justification for and purpose of some fishery regulations may have been poorly explained to the fishermen. Some administrators may misrepresent measures by exaggerating secondary intentions behind the laws. And law-enforcement officials may apply the letter of the law without sufficient regard to its spirit.

Perhaps the fisherman can be excused for viewing all kinds of regulation as coming from the same interfering hand of government, although he may be dealing with several different ministries and authorities, and with legislation related to matters as diverse as safety, investment, quality control, management of effort and conservation of resources.

Management Measure	Detail or Example	Purpose or Intent
Total Allowable Catch	Of any one species, for a whole fleet or country	Conservation of resource
Vessel/Fisherman Quotas	Maximum weight of species permissable per trip	Equalization of resource share
Fishery Limits	12-mile coastal limit	Protection of inshore fishermen
Closed Areas & Boxes	Closed bays & estuaries Haddock box, Pout box	Conservation of certain species
Closed Seasons	Prohibition of fishing during certain months	Protection of spawning fish
Moratoriums	e.g. Herring, North Sea, 1977-1982	Emergency measure to let stocks recuperate
Foreign Vessel Tax	On estimated catch from within EEZ	For revenue, foreign currency
Landing Prohibition	e.g. Berried lobster, undersized cod, etc.	Protection of immature or spawning fish
Vessel Restriction	Limited by size or power from any given area	Protection of small-boat fishermen
Licence Fee or Fishery Rent Tax	Applied or suggested for limited entry fisheries	Prevent windfall profits and share rent with State
Licensing	Of vessels	Facilitate control of fleet size & power
Licensing	Of fishermen	Provide job security & bargaining power
Licensing	Of gear (usually fixed gear)	Prevent conflicts & over-exploitation
Gear Restriction	Minimum mesh size	Reduce fishing mortality of juveniles
Gear Restriction	Overall gear size	Equalize effort & opportunity per unit
Gear Restriction	Specific gear prohibition	Reduce fishing effort and/or prevent excessive fishing mortality of vulnerable stock

Development or Support Measure	Conditions	Purpose or Intent
Grant or Loan on New Vessel	Size, type, fishery, specification. Qualifications and experience of applicant	To maintain a modern efficient fleet and direct development in approved ways. Also to encourage vessel ownership by fishermen
Vessel Withdrawal Compensation	For licensed boats within over-capitalized fishery	To reduce overall fleet size and effort, and so prevent over-exploitation and stabilize earnings for those left in the industry
Subsidy on Landed Fish	Species, whether gutted, size of boat & crew	To maintain supplies and support fishermen when market prices for fish are sub-economic
Fish Withdrawal Subsidy	Species offered for sale on market	To compensate fishermen when catches fail to realize minimum prices on fish markets
Internal Tax/ Subsidy on Species	Tax on high-priced easily-marketed species, used as subsidy on lower-priced less-exploited fish	To prevent over-exploitation of valuable species and encourage harvesting of less desirable fish, thus equalizing effort and encouraging market development

It might be a useful exercise sometime to identify all existing regulations applicable to any one fishery and ascertain their original purpose. One might note their current effects, side effects, nuisance value and costs of enforcement and compliance. Then one might make some estimate of the degree to which they have achieved or are achieving their original objectives. All management measures would have to be included, and not just those which apply directly to resource conservation.

The table above attempts to categorize and simplify major management and development measures and their basic purpose.

3.2 Priorities for regulations

Each interested party has a different set of priorities for fisheries management depending on their profession, training and/or invested interest. So we would expect differing approaches to management from resource biologists, economists, administrators, politicians, fish merchants and fishermen. The views of the other professions will be dealt with in other papers, here we might pause to list the main priorities for fishermen.

i) Resource conservation
Despite all the fears of biologists and the "tragedy of the commons" situation, practically all fishermen want the resource conserved, not just for the immediate future but for future generations. Any resistance to conservation measures would be due to doubts about their effectiveness or their fairness, but not to the purport of the legislation itself.

ii) Equality of opportunity
Few fishermen enjoy being in a vicious circle of unrestrained competition, particularly in an over-capitalized fishery. There is constant pressure then to aquire larger and more powerful vessels to gain a technological advantage over one's fellow. Competition itself is the spice of a fisherman's life and it is welcomed as long as it is competition by equals with the same rules and conditions applying to all.

iii) Balanced harvesting of resources
Some species are more marketable than others but most fishermen would agree it is not healthy for the marine environment to have fishing effort concentrated on a few species. A management system that can encourage a spread of fishing effort without penalising any one section of the fleet would be welcomed.

iv) Protection of inshore fishermen
The small need to be defended against encroachments by the large, the weak against the powerful. Fleets of small inshore boats need protection against uncontrolled fishing by offshore boats in their areas. Similarly offshore boats may require some protection against unrestrained fishing in their areas by distant water vessels or by foreign fleets. Compromise and adjustments will no doubt be necessary in each locality but the principle itself would be acceptable to most fishermen.

v) Freedom and flexibility
Management measures should be sufficient to maintain fish stocks and control fleet size and fishing power. But they should not over-regulate to the point where incentive is killed or opportunity is seriously curtailed. Sacrifices will have to be made but legislators should leave the maximum amount of freedom with the fishermen, consistent with the goals of management. Do not take away from the fishermen more liberty than is really necessary.

vi) Stability and prospects
For most fishermen the past fifteen years have been ones of change and upheaval. Some management measures, hastily contrived to cope with events, have been a miserable failure. Fishermen would like to view their future with some confidence. They would like a management system that tends towards permanence, one that takes the long view rather than a series of temporary or short-term measures which simply take them from crisis to crisis.

These are some fishermen's priorities. There are others and their relative importance would vary from region to region. But none are really inconsistent with those of government, research or business, and a meeting of minds on appropriate and effective measures is surely not impossible.

4. REACTIONS TO SPECIFIC REGULATIONS

4.1 General reactions

With respect to any single piece of fishery legislation, there are four main factors which will influence a fisherman and determine the degree to which he will observe the law.

The first is his judgement as to the integrity and value of the legislation. Should he feel it has little moral basis or that it is ill-designed to achieve its objective, then he will feel little compunction in breaking it.

The second consideration is the behaviour of his peers. If the law applies equally to them or if they as a body tend to observe it then he will be much happier to comply with it himself. However, if some of his fellow-fishermen are exempt from the law or if a fair number of them are flouting it, then he will tend to disregard it.

Thirdly, there is the potential reward for disregarding a regulation. Would he increase his catch substantially by doing so? Generally speaking most fishermen break regulations only when they are having difficulty in obtaining an economic catch by legal means. Under such circumstances the greater the increased catch by illegal means, the greater the temptation.

The fourth factor is the strictness of the surveillance system and the punitive measures, or put simply, the risks and costs of being caught. No fisherman infringing a regulation expects to be caught, but the possibility is there and it is obviously a disincentive. This applies more to the generally law-abiding. Fishermen will admit themselves that the half-hearted poacher is much more likely to be caught than the determined and regular one.

4.2 Fishery limits

Local and national fishery limits, closed bays or inshore areas, and "boxes" at sea are the common forms of limit lines a fisherman may meet with. The purpose of establishing such limits needs to be clearly defined and should be acceptable to the industry as a whole. It may be to protect inshore or local fishermen, or to conserve fish stocks or safeguard spawning grounds. But whatever the reason, it must have a clear basis in fact and a concensus of support from the fishermen. Otherwise continuous surveillance would be necessary and even then enforcement would simply create bitterness and detract from the respect accorded to other more sensible legislation.

Generally speaking fishermen will observe limit lines unless under economic pressure to increase their catches by any means. In all fisheries where fleets are prohibited from fishing in certain areas, one may find a small proportion of habitual poachers. These fishermen thrive on the existence of a limit, and amusingly, are usually the last to seek removal of the limit line.

Where a limit line exists to protect inshore fishermen one can rely on them to some extent to provide surveillance. Conflicts do occur however, but mainly in countries where the inshore fishermen have little economic or political power and where law enforcement is lacking.

4.3 Landing prohibitions

These take many forms. In several countries there are minimum sizes for certain fish offered for sale for human consumption. Egg-bearing or "berried" lobsters must by law be returned to sea in many fisheries. Industrial fish catches may not contain more than a certain percentage of edible fish under certain agreements.

There is little real resentment towards such landing prohibitions which most fishermen accept. Some like those for under-sized fish and percentage of edible fish in catches consigned for fish meal, may have a nuisance element. A trawler striking large quantities of small fish may face a problem in selection of acceptable sizes. There may be 2,500 small haddocks in one tonne weight of the fish.

A crew selecting and gutting several tons of the fish is bound to err with sizeable numbers of immature ones. Similarly, the presence of edible fish among trash fish is difficult to estimate with precision. But these considerations apart most fishermen would not view the landing regulations unfavourably.

4.4 Gear restrictions

These laws or by-laws may refer to minimum mesh size, use of otter boards or tickler chains, use of monofilament gill nets or nets above a certain size. This is one group of regulations whose observance depends largely on the fishermen's judgement of fairness. The questions in their minds will be:

(a) Is the regulation affording reasonable protection to a certain stock of fish or to a group of inshore fishermen?

(b) Is the regulation being fairly and firmly enforced? If most other fishermen are ignoring it, there will always be a temptation to do likewise.

It is essential that the fishermen are involved in the discussion and formation of any gear-restriction measures, and that these measures if adopted, be enforced without partiality throughout the fishery. Exceptions or loopholes will only cause bitterness and bring the law into disrepute.

4.5 Closed seasons and moratoriums

A complete ban on fishing for any one species, whether short-term or long-term, is much easier to enforce than any catch limit or quota. Fish must be sold, processed and retailed somewhere, and inspection at key centres can usually detect and prevent any violations.

From the fisherman's point of view, a complete ban is preferable in some ways to a quota. With a quota system it is easier to escape detection of infringements or to avoid compliance through legal or technical loopholes. Some fishermen will find ways of doing both. The attraction of a complete ban as compared to a TAC system is that it is usually applicable to all and the opportunities for violation are greatly reduced. There is a grain of comfort in the thought, however difficult a situation may be, that all others are in the same boat and are suffering equally as a result.

The major problem created by a closed season or a moratorium on fishing is that of alternative income. Few governments can afford to compensate all fishermen for an extended period and short-term employment ashore is seldom available. So some other marine resource has to be harvested.

For the fisherman this poses three questions. What alternative species may he fish for? How will he harvest them? And does an adequate market exist for those fish? If all three can be answered satisfactorily then the moratorium will not seriously affect his livelihood. If alternative species or market is not available then his problems are extremely serious. Technological adaptation for harvesting a different species may pose some minor difficulties but these are not normally insurmountable.

4.6 Total Allowable Catches (TACs)

For the individual fisherman or for a small fleet operating from the same home port, the vital element in a TAC measure is not the total national or regional TAC but the permitted catch allocated to each fisherman or each vessel. No matter how generously his province or country has been treated as regards share of marine resources, the individual fisherman will judge the measure by the quota assigned to him or to his vessel. If this is sub-economic or creates operational difficulties, then he will resent both the regulation and its enforcement.

One of the most disappointing aspects of quotas, particularly on groundfish in multi-species fisheries, is that they may result in the destruction of more of those fish rather than less. If a vessel has already taken its quota of, say, haddock, and is trying to make up its catch with cod, whiting and saithe or hake, it may have to kill additional haddock in large numbers in order to capture the other species. This situation, reported by fishermen in both the east and west sides of the North Atlantic, adds neither logic nor respect to TAC measures.

A second major disadvantage to quotas is that they are not easy to enforce. Fish may be passed at sea from one vessel to another. Fish may be landed at obscure ports where no fishery officer is present. Landing dockets may be forged to list quota fish under a different species name. Some fishermen will violate the regulations in these ways, and the more widespread these infringements, the less motivation there will be for a law-abiding fishermen to continue to comply with the measures.

A third problem arises with respect to pelagic stocks for which fishing may commence on a certain date. These species are more subject to market fluctuations due to the timing and volume of the landings. If, as has been increasingly the case in recent years, fishermen fear that the total catch allocations are too large, they will fish as hard as possible to take their individual quotas before the annual stock is depleted. This results in sudden market gluts ashore and consequent falls in price with good edible fish often consigned to industrial plants for reduction to meal and oil.

Daily or trip quotas have been tried to prevent gluts on the market; these work best with demersal fish. Pelagic fish are caught in quantity and a vessel may search for them for a whole week before making a set. In such circumstances a strict daily or trip quota can only create frustration and increased bitterness for the men who are trying to earn a livelihood.

When vessels from different countries fish side by side on the same grounds under a quota regulation, the system of enforcement must not just be fair but be seen to be fairly and firmly applied to all. In the EEC common pond system, enforcement is the responsibility of the country to which the vessels belong. Fishermen from some countries felt that other governments turned a blind eye to infringements by their vessels. Whether their suspicions were justified or not, they existed, and this in turn motivated them to look for ways of getting around the quota regulations.

Fishermen's attitudes to quotas may be summarized in three statements or expressions of opinion. They do not work. They are difficult to enforce. And they are often unfairly applied or allocated.

4.7 Internal species tax

This is a measure taken by fishermen to equalise opportunity amongst themselves and to prevent over-exploitation of a valuable species. A tax is levied on the valuable fish, say cod, and is used to subsidize the price of a less valuable and less exploited fish, say redfish or saithe. Without the tax, most vessels would fish primarily for the cod and ignore the other fish. With the tax/subsidy, a substantial number of vessels will turn their attentions to the less desirable fish. There is then less intense pressure on the valuable fish and the species previously ignored, begin to be harvested in quantity.

The measure then (it is hoped) has a third effect. Fish merchants, faced with increased quantities of cheaper fish, look around for new outlets for them and have them promoted in retail shops and restaurants. Consumption of the unfamiliar species rises and consequently their price rises. So the fleet of vessels concerned enjoys increased income from increased volume of landings and later further increases from higher prices for previously cheap fish.

This system has been tried in only a few isolated cases, as in Iceland, so it is too early to gauge fishermen's reactions. It is obviously an idea with some potential but which also calls for considerable cooperation and short-term sacrifices by the fishermen. Nevertheless, it could be useful in spreading fishing effort in certain cases.

4.8 Licensing and licence limits

The natural reaction of any fisherman to licensing must be negative. Traditional fishermen in particular, born into a fishing family or into a fishing community, will regard their entry into the industry (and their sons' and grandsons' entry) as a birthright which ought never to be relinquished.

Licensing then will never be a popular idea, initially with fishermen. At best it may be regarded as a necessary evil. To accept a system that will thereafter limit entry into their fishery, the fishermen must be convinced that the alternative is much worse. Retention of the status quo may result in a vicious circle of more or larger vessels and less fish all round with consequent survival of the fittest and extinction of large numbers of otherwise viable fishing units.

The most vociferous opposition to licensing usually comes from the highliners or top fishermen who are most likely to gain in a free for all situation and who would be at the forefront of technological innovation with larger, more powerful and better equipped vessels.

As with much other fishery regulation, a great deal depends on how fair the licensing system is seen to be, both in concept and in implementation. If it really will conserve stocks, stabilize incomes and make for a more prosperous fishing industry in the long run, then it stands a fair chance of acceptance. But if there is any suggestion of favouritism, special interests, paternalism or betrayal, then naturally no self-respecting fisherman will support it. The full participation of the fishermen at all stages in formulating and implementing such a fundamental change in management is absolutely essential.

One aspect of licensing that would in the long run receive the support of most fishermen would be limitations to the size or power of individual units. This prevents over-capitalization and thus undesirable increases in catching capacity or fishing effort. But it also prevents a small number of fishermen from taking the lion's share of the catch and growing excessively rich at the expense of the others.

Most licence limitations to vessel size have in the past been related to length or tonnage. Fishermen have found ways round these criteria by installing greater engine power and heavier equipment and by constructing vessels designed to gain maximum advantage from the legal or statutory definitions of length or tonnage.

A limit to total engine power would be much more realistic and this has in fact been applied to some fisheries. The criteria for determining engine power can be related to manufacturer's authenticated specifications, or to approved tests by certified marine engineers or surveyors. The latter would be essential in the case of devoted engines or marinised engines and an official seal would have to be placed on the governor. Thereafter any infringements would be treated seriously with possible loss of licence as a penalty.

Licence limitation by total engine horsepower would then have benefits in terms of equity, control of fishing effort, prevention of over-capitalization and reduction in total fuel consumption. Great care would be necessary in determining power limits for vessels operating in different areas and with different gear types, but most fishermen would support these measures in the long run.

4.9 Licence fee or fishery tax

In limited entry fisheries more than others it is possible for some fishermen to obtain high earnings in a short period of time. This phenomenon may occur in the early stages or may recur from time to time during years when yields are high and markets are buoyant. Some economists view this as a bad thing and suggest a fishery rent tax or imposition of fishing-licence fees.

Of all the management measures referred to in the foregoing pages, this must rank as the most obnoxious to the fishermen. For generations they may have struggled to extract a livelihood from the sea in the face of many hardships, fluctuating stocks, poor or limited markets and exploitation by merchants or vessel owners. Now when they are finally to reap a significant reward for their efforts, some artificial ceiling is to be placed on their earnings. It is not as though they do not already pay taxes on their incomes, personal incomes and vessel incomes, plus levies on fish landed for all sorts of purposes, plus taxes on fuel oil and some other purchases. No, on top of all that, some economic advisors suggest a further heavy licence fee or fishery tax.

A heavy licence fee would discourage primarily the average and below average fishermen. The top fishermen would always be able to afford it. It could result in unnecessary withdrawals from the industry during years when available fish stocks were low. The other social and economic costs would have to be considered. A fleet composed of many units of modest fishing power would support numerous secondary industries ashore in boatbuilding, engineering, net making, ice manufacture, electronics, marketing, transport and processing. To jeopardise the health and stability of the fleet which is creating and supporting secondary industry for the sake of an additional tax would appear to be unwise.

If a special fishery tax were to be introduced it would be much fairer from the fisherman's point of view to relate it to excessive vessel profits and make it a kind of surtax. Thus a vessel with a replacement value of say $1 million might be eligible for a fishery tax on all pre-tax profits over say 30 percent of replacement value. The fishery tax would be at a rate which would still leave something for the owners after payment of other taxes. But to a fisherman the tax would still be rather pointless. Under a well-formulated licence arrangement it should not be possible to increase the fishing power of any unit or replace it with a more powerful unit, without buying out another licence. So any increase in income might be invested in minor vessel improvements but could seldom be invested in additional fishing capacity. Presumably the income would be invested in some other way of benefit to the community or the country.

Some economists have suggested a landings tax as an alternative to a licence fee. The government would exact a duty on all fish sold by licenced fishery vessels. This would have two obvious results. The fishermen would fish harder to land more fish and make up earnings lost by the tax. This would be more pronounced during lean years and would result in increased pressure on the very fish stocks the licence was devised to protect. A second effect would be increased cost of fish to consumers since there would be considerable pressure by the fleet to push some of the tax cost on to the market price. So the housewife would end up paying part of the landings tax.

Experience in limited entry fisheries to date would appear to suggest that the benefits reaped from having a stable and prosperous fishing fleet, creating wealth and supporting ancillary industry ashore, are too valuable to risk by over-taxing the primary producers.

For most free-entry fisheries the arguments about fees and taxes are rather academic at present, and in any negotiations on limited entry are a bit of a red herring. Windfall profits are being reaped by very few fishermen in unregulated fisheries. Many who made large sums of money with big new purse seiners, lost most of it shortly after when they were hit by increased fuel prices, high interest rates, quota allocations and/or depressed markets at around the same period of time.

Fishing has always been marked by brief periods of high earnings. These must be viewed in the light of two things: (a) the prolonged periods of low or modest earnings, and (b) the enormous risks involved.

Fishermen do not enjoy the security or benefits that go with more stable jobs on land. They get no holiday pay whatsoever, no job-related pension, no guaranteed wage in case of catch failure, and no cost of living increase other than what the market affords, and it usually lags behind price increases for fuel, equipment, stores and services.

Statistics show the risks to life and limb which fishermen face are much greater than those in coal-mining, fire-fighting or any other major dangerous occupation ashore. In addition there are the financial risks in building or purchasing a vessel for which the fisherman has probably invested his life savings and mortgaged his home.

When occasional high earnings are viewed against the indirect benefits of having a viable fishing fleet which is making no demands on the exchequer for subsidies or welfare payments; and when they are weighed against the risks fishermen face and the periods of low earnings, then the idea of placing a high fee or fisheries tax on the primary producers appears to be both mean and self-defeating.

There are other much better ways of preventing windfall profits and sharing fishery wealth with the government and the community. One such method would be to eliminate gradually all large and powerful vessels from the fleet and retain only smaller powered units up to the minimum size deemed necessary for safe exploitation of the waters in the region concerned. Each unit would then be limited in capacity and fishing power and would be less likely to make excessive profits. Nevertheless, each unit would be more productive than in a free entry fishery and would be yielding tax revenues to the State and supporting numerous ancillary workers ashore. Fishermen employment would also be maximized, a matter of considerable help to any economy in these days of recession and unemployment.

This kind of management of units of effort could be implemented in distinct national fisheries where all operators are subject to licensing regulations. It would be difficult to achieve in fisheries where fleets from several states operate on the same grounds. But it might still be possible in common pond situations like the EEC, though only with the agreement of all member States.

5. POLITICAL EXPRESSION AND COMMUNICATION WITH GOVERNMENT

Poor communication is one of the major obstacles in achieving understanding between fishermen and government. Fishermen have difficulty expressing themselves to government, and governments generally have difficulty in understanding the fishermen's point of view. Conversely, government statements may be misunderstood by fishermen and its actions misinterpreted.

There are three main causes for this communication failure and they ought to be examined if a serious attempt is to be made to remedy matters.

5.1 Geographical and cultural isolation

Fishermen are isolated from others by the nature of their work and of their settlements or communities. The greater part of their time is spent at sea in almost total isolation from society. Their short periods ashore are largely spent in their own close-knit communities with their particular values, world view and way of life. The geographical and cultural isolation of fishermen makes them a more difficult group to communicate with than farmers, miners, truckers or other workers who also suffer from isolation or inaccessibility.

It takes time to set up a consultative meeting with fishermen. They need time to get ashore and to get from their towns or villages to the government office which is usually located in a city. Even if only one or two fishermen's representatives are called for, they need time to consult their fellows and to get authorization or guidance on negotiating positions and tactics. It would be better if government investigative bodies or consultative teams would spend a reasonable time in each of the main fishing centres, hearing testimony or reactions and answering questions. But that is an experience they are usually disinclined to submit to.

5.2 Inarticulateness of fishermen

Fishermen are remarkably articulate in their own environment. They have their own poets, prophets and writers. At sea they are expert in verbal communication by radio-telephone and ashore they have no problem in expressing themselves to fish buyers, boat builders and net makers. However, bureaucratic and diplomatic language and procedures are quite alien to them and they can fail to convey articulately their views and desires to government.

Inarticulateness may be evident in several ways. To begin with fishermen find the maze of government bureaucracies quite confusing and may be unaware of the correct procedures or channels to follow in expressing a complaint or request. Secondly, they tend to be oral communicators and dislike having to put pen to paper. Many fishermen cannot understand why an oral expression or application is not sufficient for government. It is normally all that is necessary within his own environment. Thirdly, fishermen are not familiar with the language of law, bureaucracy or diplomacy. They may use such terms themselves without regard to their precise legal connotation and may read into diplomatic language by government officials, more or less than it was intended to convey.

As a result of this communication problem it may be very difficult to arrive at an understanding with fishermen though on the other hand it may be easy to pass legislation before the fishermen have realised its full implications. This may explain partly why fishermen so often appear to protest after the event.

5.3 Vehicles of expression and representation

Of all groups of primary producers, the fishermen must surely be the worst organized. The lobbying power and influence of farmers' and miners' unions is renowned. What group of fishermen ever brought down a government or changed the direction of trade or industrial law? Only perhaps those fortunate enough to be in a country where fishing was the major or one of the major national industries.

In almost no country can any single organization speak with authority on behalf of fishermen. Instead we have a proliferation of organizations and elected representatives. In this respect the

fishermen are perhaps their own worst enemies but one suspects that other vested interests prefer to keep the fishermen divided and disputing among themselves. In the UK, for instance, there are regional fisheries associations and associations organized by species fished. There are fish producer organizations, fishermen's cooperatives, trawlermen's unions and a fishermen's federation. Elected representatives a fisherman may approach include Regional Councillors, Westminster MPs, and Euro MPs.

In some countries, federations or associations representing large fishing companies have enormous political clout, while those representing small-scale fishermen or owner-operated vessels are both fragmented and poorly represented. This may result in excessive government support for big companies or industrial fisheries and neglect of the small-scale sector which actually produces most of the fish in the majority of countries.

5.4 Confusion of issues and interests

Fishermen's interests in management measures fall into two overlapping categories, namely vessel size and sphere of operations, and fishing gear or species harvested. Each category has three main sub-divisions as follows:

(a) Vessel size and sphere of operations:

- i) Inshore boats operating close to land and usually within 10 to 30 miles of their home port.
- ii) Offshore vessels operating within the 200-mile zone in national waters.
- iii) More distant-water vessels fishing in international seas, within the EEZs of neighbouring states, or in "common pond" areas of their own waters.

(b) Fishing gear and species harvested:

- i) Demersal fisheries or trawler fleets.
- ii) Pelagic fisheries or purse-seine fleets.
- iii) Shellfish fisheries or coastal fleets.

The particular designations may vary from country to country and there may be additional groups or sub-groups but the broad divisions remain similar. Note that each size and area category may overlap with each gear and species category. This leads to confusion of issues and interests.

Add to those interest groups the various vehicles of political expression and representation and it is small wonder that fishermen's protests and lobbying are characterized by confusion and discord. Certainly the public, if not the government, is rarely able to appreciate what the fishermen want.

The meanest trick a government can play on fishermen in such circumstances is to use testimony from one group to discount the pleas of another whose interests are totally different. A classic example of this occurred when one country signed the EEC common fisheries policy. The domestic fleet appealed for a 50-mile exclusive limit within the common pond. But the trawlers federation, none of whose vessels operated within 100 miles of the country stated that six miles was more than adequate. The government of the time jumped on this as justification for signing away access to all the inshore and nearwater fishing grounds.

5.5 Principles of communication and negotiation

The task of a Fisheries Administrator faced with a confused mixture of appeals and demands is to negotiate skillfully and impartially to ensure that no one group of fishermen suffers unduly. If sacrifices are called for to achieve conservation of fish stocks he must see to it as far as possible that the burden is equally shared by each group.

However tiresome the procedure may be, governments should ensure that the views of every legitimate fishermen's group be heard and not just those of the most powerful or most vociferous.

Spokesmen for fish merchants, processors, plant owners or other shore industry should not be allowed the pretense of speaking for the fishermen. Similarly, companies and businessmen owning fishing vessels are a different breed from fishermen and have different priorities.

When a group of fishermen are in serious economic plight, their leaders - having little bargaining power - may accept a settlement that they feel is unjust or extortionate. Such an achievement in negotiations may prove to be a hollow victory in the long run for the powers that be. It would sow the seeds of discontent, bitterness and inclination to violate regulations which could jeopardize the success of any fishery management scheme.

6. FISHERIES OF INDUSTRIALIZED COUNTRIES

6.1 General description

The fishing fleets of the industrialized states are characterized by power, sophistication and versatility. Even small inshore boats may be equipped with radio-telephone, radar, echo-sounder and hydraulically operated steering gear, winch and net hauler. The investment cost of most fishing units lies in the range of $50,000 to $1,500,000. This is in contrast to developing country fisheries where individual fishing units may cost from $1,000 to $300,000 with the vast majority costing less than $10,000.

Numbers employed in the catching sector are modest. Catch per fisherman varies from about 20 tons to 60 tons for human consumption and from 100 tons to 300 tons for those countries with large industrial fisheries. So the production per man is from ten to a hundred times that of the least developed countries (LDCs).

As most industrialized countries are located in the temperate north where there are less species, this is reflected in the catch, both in its composition and in the smaller number of methods used in harvesting.

Despite the enormous power and sophistication of the industrialized country fleets it would be a mistake to assume that the bulk of their production is from large vessels. With the exception of a very few countries like the USSR, most developed country fleets are composed of vessels of less than 100 tons.

In the UK, for instance in 1981 there were only 239 trawlers above this size and they took only 21 percent of the demersal catch. The other 342,000 tons was taken by 1,976 smaller vessels.

6.2 Conflicts between fleets

The developed fisheries are being harvested at levels close to and sometimes rather beyond sustainable yields for some species, and by fleets of vessels equipped with powerful and sophisticated aids to fish location and capture. Both the overall level of effort and the intensity of the competition make conflicts inevitable. These arise between fleets of inshore and offshore vessels and between local and foreign vessels.

Because inshore fleets are limited in the distance they can travel, they are vulnerable to local fluctuations in inshore stocks. Even when several species are fished, the loss of one may greatly reduce annual income. It is important therefore to provide these fisheries with some kind of protection from competition by large vessels.

There is no need for large sea-going craft to fish inshore and a protective belt would not hurt the offshore fleet unduly. But it could mean salvation and preservation of a viable inshore fishery with all its attendant benefits for small coastal communities.

The extent of the protective coastal belt will vary according to local requirements, but could be 6, 12 or 15 miles with some bays or firths completely enclosed. As far as possible the local communities and local fishermen's associations should be given substantial authority over the section of the belt adjacent to them.

Offshore fishermen face two kinds of competition, that from other domestic vessels and aggravated perhaps by over-capitalization, and that from foreign vessels permitted to fish in their waters by licence or under common pond agreements. Both kinds of competition need to be controlled to limit total fishing effort to a level which will not damage stocks.

Fishermen will suffer the foreign encroachments if at least they are fully subject to the conditions of their licence. Enforcement has to be thorough and if necessary severe, and it must be implemented by the home state itself. The local fleets must be fully satisfied with the monitoring, control and surveillance of foreign vessels.

Competition within the local fleet can only be kept within manageable levels if overall effort is controlled. This will mean sacrifices but it should be the goal of administrators and legislators to minimize these and have the burden shared as equally as possible. Ultimately there must be ceilings for all fishery effort and these need to be translated into ceilings on the power of individual units of effort. This will affect primarily engine power but may also involve the type and size of fishing gear that may be used.

The goal must surely be a system of permanence. One that will ensure conservation of fish resources for generations to come, security of work and income for the fishermen and the ancillary industry workers, and one that will provide the market and the consumer with a regular supply of quality food fish at reasonable cost.

7. DEVELOPING COUNTRY FISHERIES

7.1 Artisanal fishing fleets

Most developing country fisheries have very large artisanal sections and these constitute a social and economic problem not present to the same extent in industrialized countries. Countries with particularly large artisanal fishermen populations include India, China, Indonesia, Bangladesh, Philippines, Korea, Nigeria and Brazil. Japan is perhaps the only industrialized country with an equivalent large number of small-scale fishermen, but their average incomes are high in comparison with most artisanal fishermen.

Most artisanal fishing fleets are characterized by extremely small units of effort utilizing mainly passive methods of fish capture such as gill nets, hand lines, traps, tangle nets, long lines, lift nets and cast nets. Catches per unit of effort are very low, often at marginal or subsistence level. Most of the fishing is conducted within 12 miles of land though some artisanal boats may travel many more miles from their home village.

The mechanization of artisanal fleets is limited and the vast majority of them still rely on sail and paddle for propulsion. Some experts now question the wisdom of mechanization programmes, believing that the best technological option for these craft to be a gentle combination of both sail and modest power. Of the estimated 900,000 artisanal fishing boats in the combined fleets of India, Philippines, Indonesia, Nigeria, Korea and Brazil, some 100,000 or just over 10 percent were reckoned to be mechanized in 1979 (FAO Fishery Country Profiles). Actual mechanization rates can vary from country to country, from under 5 percent to over 50 percent. Because of this, the artisanal fleets use on average only 60 litres of fuel to catch a tonne of fish compared with 300 litres consumed by commercial boats to produce the same amount.

7.2 Fishing pressure of artisanal fleets

Nearly 20 million tons of fish are caught annually by artisanal vessels. From an estimated 10 million fishermen and 2.5 million boats, that breaks down into an annual average catch of 2 tons per fisherman and 8 tons per boat. In a 200 day fishing year that would average out at 10 kg per fisherman and 40 kg per boat each fishing day.

Catch per unit is low because of the simple technology used and because of the sheer numbers of vessels concentrated in some localities. However, because the methods used are mostly passive and unsophisticated, pressure on the resource may not be too great. Catches per unit may decline if fleets increase in number but the stock itself may not be threatened if only artisanal boats are working it.

This is an extremely important fact both from the point of view of resource biology and of socio-economics. Sedentary species and marine mammals have been over-harvested, but to date there are no cases of a fish stock being destroyed by the actions of artisanal fishermen. All the drastic resource failures of the past 30 years have been due to the pressure of commercial or industrial fleets. The Peruvian anchovy, the South African pilchard, the North Sea herring, the Californian sardine and the whales all succumbed to such commercial efforts. The depressed state of demersal stocks in S.E. Asia has been brought about through over-capitalization in the trawl fisheries. In none of these cases did artisanal fleets, however large, play any more than a very minor role.

Problems arise when commercial fleets begin to operate in artisanal fishing grounds as has been happening in the Philippines and Indonesia. Then over-exploitation may well occur, but to blame it on the artisanal fishermen is a dishonesty and an injustice which adds insult to injury. Yet this view has been advocated at times in an effort to justify continued commercial operations on artisanal fishing grounds.

7.3 Enforcement of fisheries regulations

A major problem for any poor or under-developed country is the cost and technical demands of monitoring, control and surveillance. It is relatively easy to pass a law prohibiting fishing in a certain area, but if there is no fishery protection vessel to apprehend offenders, then the law becomes worthless. It is worse than no law because on paper at least there should be no cause for complaint. A similar situation exists if the powers of arrest and charging with offences lie with very junior local officials. A large and wealthy company can intimidate such persons with ease by one means or another.

There are some countries which have had fishery prohibitions on the statute books for many years and yet have not had a single successful prosecution against a commercial fishing company although hundreds of artisanal fishermen may have been tried and punished for similar but smaller violations.

A law is only as good as its enforcement. If the enforcement mechanism is lacking, the law has no teeth and is of no help to the fishery. Fishery management in developing countries may therefore be an impossible task until a competent protection service is established, large enough to police the waters and with sufficient authority and integrity to be able to do so without fear or favour.

Perhaps the Japanese system of management of coastal zones by local authorities with their own protection service may be a guide for such situations. Local fishermen's leaders and elected community representatives guide the management authority in its monitoring, control and surveillance activities. Alternatively, a strong Federal MCS unit as established in Malaysia might be able to effect enforcement without yielding to influential local business or political interests.

8. CONCLUSIONS & SUMMARY

For fisheries legislation and management measures to be really successful, the cooperation and agreement of fishermen is very necessary. The fishermen should be consulted and involved at all stages of the conception and formulation of regulations.

As most fishermen are to varying degrees members of rather inaccessible and inarticulate groups vis a vis government bureaucracies, special efforts in communication and liaison are necessary for proper consultation.

Fishery regulations should be adopted only after fishermen and administrators are satisfied that they would achieve the desired objectives, would be fair to all groups affected, would be enforceable at acceptable cost and would not have any serious side effects.

Control of fishing effort is scarcely possible without fixed limits to fleet size and fishing capacity. The most realistic measure of fishing capability is engine horse-power. Vessel length and tonnage are extremely poor guides. So a limit may have to be placed on the engine power of individual units. Some gear control may also be necessary.

Failure of management measures in developed countries can hardly be blamed on lack of enforcement facilities, data or research. Rather it has been due to poor work in the conception and formulation of regulations.

Developing or poor countries have different management priorities particularly as they mostly have large populations of artisanal fishermen with no alternative job prospects. As most LDCs are located in the tropics where many species of fish abound, they also have more complex stock management problems.

In both developed and developing fisheries, substantial protection should be afforded to the coastal belt for the benefit of small-scale fisheries and inshore stocks.

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SOME EXAMPLES OF SELF-REGULATORY MECHANISMS IN UNMANAGED FISHERIES

by

James R. McGoodwin
Associate Professor
University of Colorado
USA

Abstract

This paper reviews a great variety of indigenous and/or traditional mechanisms of self-regulation employed in unmanaged fisheries. The discussion treats the following categories of self-regulatory mechanisms: unregulated, unmanaged fisheries; passing mechanisms of self-regulation; and active mechanisms of self-regulation. Throughout, these self-regulatory mechanisms are discussed with a regard for their possible relevance and efficacy in future policies for the management and development of small-scale fishermen and fisheries.

Now that it would seem the world's coastal nations have basically secured control over their fisheries to 200 miles from their shores - spelling the end of nearly four centuries of the doctrine of "the freedom of the seas" - there is great worldwide concern for determining new management regimes for these fisheries' future management and development.

This concern comes at a time when the world economy is experiencing great instability, and when many fisheries find themselves in great trouble owing to overharvesting and chaotic competitive pressures. At the beginning of the colonial era - only a little over four centuries ago - the world's human population was only about a half billion inhabitants. Not it is around four to five billion, and by the end of this century will be nearly eight billion (Idyll, 1978). News of acute food shortages in vast world regions appears with increasing frequency. Truly, these are important times for finding new ways to manage and develop the world's fisheries, especially if we are to address the problem of scarce food facing much of humanity.

This paper presents examples of some of the methods by which unmanaged fisheries attempt to regulate themselves, that is, I focus upon so-called indigenous or traditional systems of fisheries management (cf. McCay, 1981; Klee, 1980). By "unmanaged" fishery, I mean a fishery not otherwise regulated under the central authority of a government-controlled managerial regime or a fishery which, while managed by a central external authority, undertakes its own regulation to some degree. I shall also briefly discuss a few examples of unmanaged fisheries which apparently do not regulate themselves, since these provide interesting points for comparison and contrast.

I will begin by looking into the idea that primitive, pre-colonial and/or pre-industrial humanity lived in a state of harmony, balance and/or equilibrium with nature, citing a number of instances where such was decidedly not the case. This is followed by some observations of societies which do or did not regulate their fisheries, and with varying results. Then I will turn to a discussion of "passive" self-regulation, by which I mean situations in which, while it may not be the conscious intent of a people to regulate their fisheries, certain aspects of their socio-cultural system have that effect.

These matters presented, I will turn to the main body of this discussion: active, purposeful self-regulation in otherwise unmanaged fisheries. This discussion will suggest a number of methods which may be appropriate and beneficial in the future management of inshore and coastal, artisanal, peasant and/or traditional fisheries and fishermen, and should also shed some light upon the basic nature and characteristics of such peoples.

The reader is cautioned to bear in mind that my division of examples into the categories of "unregulated", "passively regulated", and "actively regulated" fisheries is largely arbitrary and does not necessarily correspond with any such clear distinctions existing in reality. Obviously, an unregulated fishery may also be conceptualized as passively regulated, or an aspect of passive regulation - especially when effective - could be argued to be an active factor in fisheries regulation. Thus, my conceptual sub-divisions should not be taken as particularly important, but rather the reader should focus on the examples themselves, seeing how each factor presented - regardless of how it is categorized - may contribute to fishery regulation, limiting entry, effort or mortality, and so forth.

My units for analysis throughout are tribal, peasant, traditional, artisanal and/or small-scale fisheries and fishing peoples. I will not be particularly concerned with self-regulating practices among large-scale, industrialized fisheries and fishermen, although a few examples of self-regulating behaviour may be drawn from these. Again, the reader should be concerned with process not definition. Obviously, there is no fine line of distinction, for example, between small-scale commercial and industrial-scale fisheries and fishermen.

The reader is also cautioned not to associate my focus upon mostly small-scale fishermen as a focus upon the less important, perhaps more romantic side of fishing. Small-scale fishermen have become of enormous concern as units for fisheries investigation in recent years, as increasing information concerning their relative importance has come to light. No longer are they viewed as merely quaint, colourful, backward or even unprogressive, as compared with large-scale, industrialized fishing enterprise. Indeed, in many circles they are coming to be seen as the wave of the future in world fisheries.

Compared with large-scale, industrialized, company-owned fishing enterprise, for example, small-scale fishing enterprise offers a number of distinct and important advantages. For one thing, they produce about 45 percent of the total world catch, and employ roughly 18 times more fishermen than does the large-scale sector. Nearly all their production is designated for human consumption, and their capital-cost per job provided is roughly one hundredth that of the large-scale sector. Further, the small-scale fishing sector's consumption of fuel oil is only about 11 percent of the total fuel oil used in all commercial fishing, and per tonne of fuel oil consumed it produces nearly five times as much fish. In human terms, the importance of the small-scale fishing sector looms large indeed. While it is estimated that worldwide there are only about a half million fishermen working in the large-scale sector, FAO estimates there are about 10 million small-scale fishermen, each of whom create an additional two to three jobs ashore. Counting the families and dependents of small-scale fishermen, that sector supports the welfare of over 100 million persons worldwide (Thomson, 1980). Given these aspects of productivity, economics, efficiency and human involvement, the small-scale fishing sector would seem of paramount importance in future policies for fisheries management and development.

Unregulated, Unmanaged Fisheries

What of unmanaged fisheries which do not seem to have mechanisms for self-regulation? What is the experience in these?

It has been often presumed that long ago, before the advent of modern technology and high human populations, humanity's impact on nature was small and, having only a rudimentary technology, humanity lived in basic harmony or equilibrium with its food resources. For the most part, as we review the long run of human evolution and history, that would seem generally to be the case. But such has not always been the case in all instances.

Hennemuth (1979), for example, doubts that humanity evolved in harmonious equilibrium with marine ecosystems in the same manner as proposed for terrestrial adaptations. He notes that marine organisms basically did not co-evolve with humanity and states "There is some doubt that man

can be a prudent predator (i.e. in the marine environment), taking only what would die or not be produced in his absence".

There is ample evidence that pre-historic humanity sometimes wasted resources and, through unrestrained effort, may have occasionally jeopardized its precious food supplies. Such behaviour can possibly be interpreted as an exception, if not contradiction, to the behavioural processes foretold in the so-called "tragedy of the commons" (Hardin, 1968). Unrestrained effort leading to over-harvesting is only supposed to occur in a common-property, open-access situation in which there come to be too many competing producers, and while in the Pleistocene era, for instance, we may presume human population to be relatively very low, and production technology quite primitive, nevertheless we encounter instances in which Pleistocene-era peoples apparently over-harvested precious food supplies.

Good studies have recently come to light which conclude that early humanity in the Pleistocene era sometimes played a central role in the depletion, over-harvesting, and sometimes total extinction of important food resources. Smith (1975), for example, offers data supporting an hypothesis that over-kill by Paleolithic-era hunters in some world regions led to the extinction of many of the large herding animals upon which such peoples depended for subsistence. Of course, such animals were less numerous relatively than fish and required far longer time to reach reproductive age, both factors which Smith concedes made them particularly vulnerable to both over-harvesting and extinction.

Yesner (1980), discussing pre-historic maritime hunter-gatherers, cites various instances of disastrous over-harvesting in marine ecosystems. His examples come from archaeological accounts: those of Shawcross (1975) and Swadling (1976), for example, describing resource depletion arising from over-harvesting in pre-historic New Zealand, or Kirch (1979) and Reinman (1967), describing similar situations in various parts of Oceania, and Yesner's (1977) own studies indicating how pre-historic maritime peoples in Alaska over-exploited their main food resources.

At a less remote time - the Formative (pre-Inca) era in Peru - Moseley (1975) presents convincing evidence that the coastal civilizations of that time periodically over-harvested their main subsistence resources - marine clams and oysters - to such an extent that they were forced to shift to other modes of subsistence (i.e. agriculture). Finally, Johannes (1978), in an important work concerned with traditional methods of marine resource conservation in Oceania, records a number of instances where unrestrained harvesting practices led to the depletion of important subsistence resources. In the Solomon Islands, he notes, porpoises were harvested for their teeth while their valuable meat was left to rot in the sun; and in many parts of Oceania, poisoning was used as a fish-producing method, a process which indiscriminately killed both fry and eating-size fish. Both the Trobriand and Hawaiian islanders, he further notes, often engaged in wasteful over-harvesting, leading to food-resource depletion. The natives of Satawal over-harvested turtle eggs, depleting that resource, and "horrible waste was sometimes committed by the Tahitian royalty at their feasts" (Johannes, 1978). Johannes is quick to add, however, that these depradations were an exception to the more general pattern of wise resource management seen throughout most of pre-colonial Oceania.

What all the foregoing examples should make abundantly clear is that primitive, pre-colonial and/or pre-industrial humanity did not always live in a state of reverential, harmonious equilibrium with nature, being ever careful to insure itself a sustained supply of vitally-needed subsistence foods. Thus, modern man is not unique in his capacity for wastefulness and greed, even if he is unique in terms of the scale and extent of his wastefulness.

There are many other examples, of course, of situations in which pre-industrial peoples apparently made little effort to regulate their fishing effort, and yet suffered neither the ill effects of resource depletion nor disastrous competition. Firth (1965), for example, in his account of primitive Polynesian economy, notes that the fisheries were common property, that no resources were owned, and that people survived without experiencing resource depletion or severe internal competition. Davenport (1960), in his account of the artisanal pot-fishermen of modern-day Jamaica, states that these fishermen enjoy no permanent sea tenure over prime pot-fishing areas - and perhaps not even temporary preferential access - and yet do not experience resource depletion or competitive conflict over pot-fishing space. Gladwin (1970), in his description of the people of Puluwat, Micronesia, makes no mention of any constraints on fishing effort, and paints a very rosy picture of an open-access, highly productive, unregulated, problem-free subsistence-oriented fishery, by his own account

Puluwatan population is small, marine resources abundant, and the possible territory available to them for fishing immense indeed. Finally, Orona (1968), describing artisanal fishermen of Isla Margarita, Venezuela, says these may fish anywhere they wish, without restraint of any kind, and apparently without suffering either resource depletion or competitive conflict.

The problem with such accounts, above, is that many are nearly anecdotal, presenting little data or descriptive material that would facilitate cross-cultural, trans-regional comparisons. They seem almost idyllic in nature, sometimes contradicting our informed intuitions or even common sense, and whatever the case, they are exceptions to the more frequently observed situation in today's small-scale, non-regulated fisheries. The usual case today - the situation we most often encounter in unregulated fisheries - is one of conflict and contention over resources, and severe harvest pressure. This is particularly the case in fisheries' regions where human population is high, the level of societal integration hierarchic or complex, harvest technology fairly advanced, and resources are either relatively immobile, or are confined to a limited number of spots or regions or only available at certain times. Thus, examples of unbridled over-fishing in the small-scale fishing sector are numerous indeed.

In one study, Kesteven (1976) notes instances where whole stocks were wiped out by artisanal fishermen using simple haul-seines in Indonesia, and a similar among weir and bag-net fishermen taking migratory stocks on the Tonle-Sap River of the Grand Lac of Cambodia, or the nearly total depletion of migrating shrimp stocks taken in bag-nets by fishermen operating near the mouth of the Rokan River, Sumatra. Kesteven also cites numerous other similar instances of over-harvesting by artisanal fishermen in diverse parts of the world; Indonesia in general, Thailand, Malaysia, Singapore, the Philippines, and among fishermen employing tuna traps around Sardinia in the Mediterranean Sea.

Bell (1978) raises the issue of a society's "time preference" concerning whether or not it will undertake the self-regulation of its marine resources. "In simple terms", he says, "if a society is on the verge of starvation, its members could not care less about over-fishing ... there is no tomorrow for such a society ... they have a short time preference: they would rather consume the fish today than save the fish for harvest sometime in the future ..." (p.148). I have witnessed this same sort of behaviour myself, in an impoverished region of rural Pacific Mexico, where individualistic artisanal fishermen, seeking to provide food for themselves and their families, take considerable risks to poach in a severely over-harvested, already-regulated fishing territory.

Another well-known case in which unregulated effort led to resource depletion was the widespread practice of dynamite fishing, particularly in the Philippine Islands. Until this practice was finally curtailed in the early 1970s, it had a disastrous effect on both marine resources and marine environments. Arising early in this century, dynamite became widespread among Philippine artisanal fishermen and eventually even became destructive of the highly-productive, long-established corral-fishing sites (Spoehr, 1980).

Fraser (1966), in his account of artisanal peasant-fishermen of south Thailand, describes a situation in which these fishermen were subjected to so much competitive pressure from larger-scale, offshore commercial fishermen, that they soon found themselves in a situation of unrestrained competition (i.e. amongst themselves), a change which not only further exacerbated the scarcity of their main subsistence stocks - mackerel - but which also was a contributing factor in the breakdown of traditional forms of social and economic organization, many of which had relevance to their fishing behaviour. As offshore, large-scale fishing enterprises rapidly depleted the mackerel stocks, the artisanal fishermen operating inshore began to harvest the mackerel stocks as if there were no tomorrow.

A similar situation is also reported by Dickinson (1974) among artisanal fishermen of Lake Izabal, Guatemala. The fishery - a common-property, open-access resource - has experienced a chaotic rise in harvest pressure, accompanying a similarly chaotic rise in the human population inhabiting the shores of the lake. More effective harvest technology has also been introduced into the fishery and over recent years the catch for a given amount of effort has declined substantially. "The response to a dwindling catch", Dickinson observes, "has been to fish more diligently, and acquire more nets" (p.396), precisely the type of behaviour foretold in Hardin's description of "the tragedy of the commons" (1968). These are not mere isolated cases. Scott (1952) reports that, in the inshore fisheries of South Africa, artisanal fishermen engaged in such unrestrained effort that they were the main factor

promoting resource depletion and severe competition amongst themselves, to such an extent that the central government was forced to impose restraints on types of gear, placement of gear, mandated fishing seasons, area closures, etc. Cordell (1978), writing about marginalized artisanal fishermen fishing in a common-property, open-access fishery of inshore Brazil, notes that these take as their main catches vast quantities of spawning fish, and further, that adherence to tidal timing exigencies concentrates them in the same, limited number of fishing spots, leading to both heavy pressure on these spots, and severe conflicts and competition over access to them. Of course, many of the ills in fisheries such as those described above may be seen more as reactions to some new deleterious factor - the encroachment of outsiders into traditional fishing territories, or the advent of new, more effective technologies - but whatever the cause, they suggest that small-scale fishermen will engage in over-harvesting and contribute to a situation of chaotic competition in an unregulated fishing environment.

A number of researchers have noted the deleterious effects of non-regulated fishing in common-property, open-access fisheries, when traditional subsistence fisheries have undergone a transformation to production for cash income, or to supply a significantly increased market demand. Nietschmann's (1974) account of the Miskito Indians, artisanal turtle fishermen of eastern Honduras (and Nicaragua), and Johannes' (1978) account of the demise of traditional systems for fisheries management accompanying the colonization of Oceania, are both well-documented examples. In both, a traditional, subsistence-oriented economy was subverted by the advent of economic systems emphasizing production for market, and for cash.

When a people produce fish to feed themselves, and perhaps produce a surplus to either barter or sell to their immediate neighbours, a point will be reached beyond which further production has little marginal utility. When people produce fish to sell for cash - cash which they need not only for purchasing life's necessities but also which they come to feel they need in ever-greater amounts to realize the myriad, often illusory dreams which cash-and-market economic systems foist upon them - then there may be no upper bound to their fishing effort.

The foregoing has discussed non-regulation in unmanaged fisheries. In a few instances, being unregulated was seen to have no apparent ill effects but in many more the reverse seemed true. Now I turn my attention to a discussion of "passive" self-regulation in small-scale fisheries, that is, to situations in which, while it may not be the conscious intent of a people to regulate their fisheries, nevertheless certain aspects of their socio-cultural system seem to have that effect.

Passive Regulation in Unmanaged Fisheries

Just because a socio-cultural practice does not have the intent of regulating fishing effort, it does not follow that it is of little consequence for future considerations of fisheries management. In many cases, socio-cultural systems are best appreciated as the result of long-term adaptations to their environments and, if this system was harmonious and sustained a society's members, then it must have features we should consider worthy of retention in any future management scheme. Now some people trust only in intentional action, but indeed the best managed fishery may be one that is not managed at all, but rather one which has developed a well-integrated system of institutions or customs which have the effect of sustaining the well-being of all its members. Whether or not this is the situation in a particular situation must be determined case by case, since as I have already discussed not all unregulated fisheries find themselves in a happy condition of long-term and sustained productivity.

In what follows, I summarize some of the various methods mentioned in various studies which seem to at least passively have the effect of regulating fisheries.

High on the list of passive features which have the effect of preventing over-harvesting or severe competition is simple inability itself: a human population too low to do much damage, a low-impact exploitive technology, or some other combination of factors which add up to a simple inability to over-pressure a fishery. This signals an important consideration in development schemes, that even if a small-scale fishery cannot be left alone, then it should at least be developed very slowly and carefully. The nature of the socio-cultural system, its organization and functioning, as well as an estimate of the state of well-being of the populace, should perhaps be the first consideration in any development scheme, with biologically-based estimates of the fishery's production potential being a secondary consideration (implied in Cordell, 1978). Whatever course of development will be promoted,

the developmentalist(s) should keep uppermost in mind the factors that have worked for a society, attempting to retain these (or their analogues) in future management schemes.

Much has been written about the necessity for developmental innovations to be "appropriate" in the socio-cultural milieu in which they are to be introduced, and similarly there are countless accounts now of development projects which brought in inappropriate innovations, much to the target population's detriment.

Extreme caution must thus be exercised in development schemes not to undermine passive means of regulation which seem to have served a people well, whatever these may be. Whether or not a socio-cultural feature is a passive, versus an active, means of self-regulation should not be regarded as an important issue. What is important is a well-informed estimation of its effectiveness.

Not all passive features of fishery-conservation will be desirable for retention: poverty itself, for instance, which prevents people from acquiring sufficient capital to over-harvest their fishery, or poor health or poor education which essentially results in the same.

A human population too low to have a deleterious impact on stocks has already been mentioned as a passive means of fishery regulation. So has an inability to over-exploit resources because of technological factors: having boats or other craft, for example, too small to venture very far offshore or unable to carry large nets or inadequately powered for doing the same. Even the lack of ice, which prevents fishing too far from home port - particularly in warmer climates - has been mentioned as a passive means of limiting fishing effort (Cordell, 1978). Berleant-Schiller (1982), writing about artisanal fishermen in Bermuda, states that "so far, an interaction of environment, artisanal technology, and economy has protected the fishery from depletion and preserved it for local use ..."

An interesting anecdote in the vein of simple inability as a means of passive control, is Bowles (1973), noting that harbour-space limitations in certain Maine lobster fisheries effectively restricts the number of fishermen who can enter the fishery, limiting both effort and competition.

Another important passive means of self-regulation, reported in various ways by different authors, is a sort of "lower bound effect", that is, a situation in which declining productivity in a fishery eventually causes fishermen to turn to other options and leave the fishery alone. The lower bound should not be conceived of as a definite line, which is the same for all fishermen engaged in a fishery, since the relative availability of other options, and differential perceptions of these, will determine the lower bound for each fisherman. However, the idea is that a point will come in a situation of declining yields when stocks become too depleted, profitability too small, or competition too severe - or a combination of such factors - which will deter fishermen from further effort. In its most general sense, this concept is perhaps a universal aspect of fisherman behaviour, and applies regardless of whether the fishery is characterized as "primitive", "artisanal", "subsistence-oriented", "small-scale commercial", and so forth. The behaviour attending this concept can be inferred from Moseley's (1975) evidence that the ancient inhabitants of the Peru coast turned away from their fisheries (and to agriculture) once they had over-harvested the marine resources upon which they were dependent for subsistence (he also argues that this dynamic process of having to turn away from the fishery for awhile, not returning until it was restored, was conducive of the complexity of pre-conditions leading to the rise of the Andean high civilizations).

What I call the lower-bound effect has also been discussed by other researchers looking at contemporary fisheries' problems. Crutchfield and Pontecorvo (1969), for example, describe the process of "competitive withdrawal", a situation in which traditionally cooperative fishermen turn to competitive individualism as their fishery becomes over-fished, leading eventually to the withdrawal of some fishermen from the fishery altogether. McCay (1981), who has studied small-scale fishermen in New Jersey (USA), states that, as a fishery moves from a basically private-property, subsistence orientation to a common-property production-for-market situation, corresponding with an influx of more fishermen and/or more effective gear, that we again witness the tragic situation outlined by Hardin (1968) in the "tragedy of the commons". The point of "economic over-fishing", she says, will likely be reached before the point of "biological over-fishing" (p.4). Thus, when the lower bound of "economic" fishing is reached, fishermen will leave the fishery, and such behaviour may thus be seen as a passive instrument of self-regulation, no matter how disastrous the situation for the particular fishermen involved. A happier state of affairs, of course, is to maintain a fishery in a state above both the lower bounds of "economic over-fishing" and "biological over-fishing".

Another important mechanism of passive self-regulation, described in various studies, concerns fishermen turning to other activities because of other exigencies of their socio-cultural systems: economic exigencies, ritual demands, and so forth - all of which entail a turning away from the fishery even during times when continued fishing might be rewarding. Such periodic turning away from the fishery to other activities has the effect of giving the stocks a time for replenishing themselves. Lofgren (1979 and 1982), for example, describes the fishermen-crofters of the North Atlantic fringe who, at certain times of the year, leave fishing for other activities: e.g. agriculture, sheep shearing, timbering, trading activities, crafts, etc. He is joined by other researchers: Leap (1977) and Martin (1979), offering similar observations concerning the rural traditional communities of Newfoundland; Middleton (1977), describing societies of rural fishermen-farmers in Ecuador; Berleant-Schiller (1982), describing Caribbean artisanal fishermen who seasonally turn to cutting, burning, and cultivating their swiddens; and Pi-Sunyer (1977), describing small-scale fishermen in Spain who seasonally leave fishing and turn their attentions to the local tourist industry.

An important idea embodied in nearly all the above works is that it is a rare situation that finds artisanal or small-scale fishermen exclusively reliant upon fishing and, moreover, that a pluralistic occupational pattern is positively adaptive in most cases. Occupational pluralism, most of these writers agree, is not only an important factor for reducing pressure in a fishery, but reduces the risk of disaster that would be possible in any society having only one option for securing its basic livelihood.

Lofgren (1982), describing the transformation of peasant societies in the North Atlantic regions of Sweden, Ireland, and Scotland - from stable, landed peasantry of fishermen-crofters at the beginning of the 18th Century, to landless tenants almost wholly reliant upon wage-labour work aboard trawlers by the 20th Century - provides us with a particularly informative discussion of the disastrous results attending the loss of occupational pluralism among such peoples. Not only has the industrialization of their fisheries left them worse off, but the fisheries themselves are now in a poor condition: too few resources, too much pressure, such that even the industrialized sector now experiences acute problems.

Examples such as the ones cited above should thus provide stern warnings to any who would seek to convert a fishery from a system involving occupational pluralism, to one involving fulltime, industrialized modes of fishing enterprise. Craig (1966), for instance, observes that aspirations of the state, particularly a desire for generating foreign exchange through development of export trade, can have disastrous consequences for artisanal fisheries and fishermen (similar observations are recorded in Nietschmann, 1974, concerning the Caribbean turtle fishery, and McGoodwin, 1980, regarding the development of a shrimp-export industry in Pacific Mexico).

Turning periodically away from fishing to other activities may also be prompted by strictly environmental factors, such as severe weather or seasonally high tides. In northern climes, for example, the icing over of the sea or of rivers has been mentioned by Gjessing (1973) as a factor forcing prehistoric maritime hunter-gatherers in northern Norway to turn away from fishing to terrestrial hunting activities. Hewes (1973) similarly notes that icing of rivers and estuarial inlets forced seasonal cessation of fishing activities among the aboriginal inhabitants of the Pacific salmon-fishing regions of the North American northwest.

Certain customs, religious practices, superstitions, or taboos may also cause fishermen to periodically leave their fisheries alone. In much of Europe, fishing effort was long forbidden on the Sabbath (about 52 such days in every year). Both Johannes (1978) and Klee (1980) report abstention from fishing activities in widespread regions of Oceania, because of religious or superstitious beliefs, food taboos during certain times or for certain categories of people, etc., all mechanisms which undoubtedly reduced the extent of fishing effort in any given region.

Information-management behaviour, which is usually discussed as an active strategy of self-regulation, may also be seen as a passive mechanism for limiting fishing effort. Forman (1967), writing about the artisanal raft fishermen of Brazil, notes that secrecy concerning particularly effective spots is for the consciously stated aim of reducing competition at such spots, but doing so may also be seen as a passive means of limiting the harvest effort at these spots. Later in this paper I will discuss secrecy and information management as an active strategy for limiting entry or fishing effort.

So-called randomizing techniques have been argued by a few cultural ecologists as a passive mechanism for limiting effort applied to food resources. A form of divination called scapulimancy, widely reported as a hunting-search technique (although not in fishing) employed by various aboriginal inhabitants of the north circumpolar regions of North America and Eurasia, is one good example. Scapulimancy is a divinatory technique in which a shaman "reads" the char marks on a (deer or reindeer) scapula withdrawn from a fire and, from his interpretation of these, he indicates where hunters should concentrate their effort. Because, presumably, he sends hunters off in random directions, the long-term effect of this socio-cultural practice has been argued to be an important factor in limiting mortality and sustaining vital food resources (Moore, 1957). I am somewhat skeptical of such interpretations, however. Among rural shark fishermen I have studied in Pacific Mexico, while their search for sharks is initially predicated upon resort to a randomizing search technique, once they find shark concentrations they tend to harvest the concentration until their productivity dwindles, only returning to a random-search technique once contact with the concentrations is lost (McGoodwin, 1979). Seen thus, such behaviour would seem more a way to maximize productivity and not to sustain the stocks.

Technology, mentioned earlier as a mechanism for passive self-regulation by virtue of low impact and/or low effectiveness, may also have the effect of reducing harvest pressure by spacing out fishing effort, working against tendencies for fishermen to concentrate in particular spots. Cordell (1978) notes that, among artisanal fishermen exploiting an inshore fishery in Brazil, the mere fact of having different gear naturally causes fishermen to space out their efforts, since each type of gear is only appropriately applied in the micro-environment most suitable to it. The lesson in this case, I suppose, is that a diversity of gear may be a desirable state of affairs, since it avoids the problem of fishermen all having the same gear attempting to fish at the same time in a limited number of highly productive spots.

A particularly interesting mechanism for passive self-regulation of fishing effort is any sort of cultural deterrent to the use of fish and other marine life as human food. Simoons, et al. (1979) reports the existence of cultural deterrents to the consumption of marine foods in widespread parts of the world: among the aboriginal Tasmanian peoples living on the islands off southern Australia, for example, who would not eat scaled fish; or in vast areas of northeast, east and south Africa; in many parts of India and Sri Lanka, where the authors estimate as much as a third of the population never consumes marine foods; and among various indigenous peoples in the North American southwest who, because of religious beliefs and superstitions, avoided marine foods altogether. Klee (1980) also reports instances of marine-food avoidance in parts of Oceania, particularly in the Society and Hawaiian Islands. Whatever the reason for these avoidances of marine foods, undoubtedly they have the effect of reducing the demand for marine food, if not also reducing overall fishing effort in any given situation.

A final note. Hewes (1973) observes that decimation of the aboriginal population brought about by the incursions of new settlers along the North American Pacific coast in the late 18th to mid-19th Centuries, resulted in a "non-deliberate, conservational effort", regarding the region's salmon stocks such that, with the advent of the commercial salmon industry in the 1860s, those stocks were higher than they had been for millenia. Of course, nobody is going to propose decimation of a human population as a means for limiting fishing effort, but a reduction of the population devoted to fishing through means of re-settlement or re-direction to other (non-fishing) occupations should be considered as one possible means for limiting fishing effort.

Active Regulation in Unmanaged Fisheries

McCay (1978) has observed that most indigenous management schemes have actively attempted to regulate or limit access to space rather than levels of effort or, as Acheson (1981a) states "The object is not to protect or conserve the fish as much as to reserve the fish that are there for one's self". Of course, many systems of active regulation incorporate means other than merely those which regulate access to space: gear avoidance, not harvesting spawning stocks, information management, and so forth. But rights of access are usually a first or fundamental aspect of self-management in indigenous regulatory schemes. As I shall show, the preponderance of indigenous management techniques involve, in one way or another, the assertion of proprietary rights over spaces in which resources exist. As Andersen (1982) notes, controlled access to fishing space and resources is not new; it is as old as fisheries themselves. The beginnings of fisheries management, he continues, occurs

continues, occurs "when the resource is limited and fishing is susceptible to social and economic changes" (p.19). And such is the situation in most small-scale fisheries today: limited resources and profound social and economic changes.

One of the most basic means for limiting access to fishing spaces and resources is the assertion of both formal and informal property rights, mainly to deny "outsiders" access to fishing territories. And we should not assume that the notion of property rights is a relatively recent innovation in human history. Primitive hunter-gatherer bands, while not perhaps placing too much emphasis on personal property, did undoubtedly develop notions of privileged access to certain territories. And certainly, with the advent of sedentism, and especially the development of agriculture and settled life, at least community ownership of productive territory was a certain fact (Andersen, 1974).

In Japan, perhaps for millenia, fishing villages have owned (in common) their traditional grounds and prevented unwanted entry into these by outsiders. Often, the recognition and enforcement of these community ownership rights was through provincial, prefectural governments (Befu, 1981; Chang, 1971; Matsuda, 1972; Nishimura, 1975; and Norbeck, 1954). In the Philippines and throughout most of Oceania prior to European colonization, chiefs, clans, communities or families asserted ownership rights and prerogatives of administrative control over fisheries (for the Philippines see Blair and Robertson, 1903; for Oceania see Johannes, 1973, 1977, 1978; Klee, 1980; Knudson, 1970, Lessa - 1966; and Sahlins, 1958). Similarly, assertion of exclusive property rights has been observed for the highly advanced indigenous chiefdoms of the salmon-fishing regions of Pacific northwest North America (Drucker, 1965; Hewes, 1973). In the North American northwest, in what is now Washington State, individual persons among the coastal Salish Indians apparently enjoyed formalized, inherited property rights over prime oyster beds, as well as some fishing grounds (Suttles, 1974); and in what is now northwestern California, the Yoruk Indians asserted communal rights over certain beaches and coastal fishing grounds (Beals and Hester, 1974).

In Pacific-coastal Mexico, it seems that prime sites for weirs, and also particularly rich oyster beds, were under the administrative control of chiefdoms at least by 1,200 A.D. (Scott et al., 1971).

As early as the 13th Century, and perhaps much earlier, the royal kings of Britain asserted both rights of ownership and rights of administration over prime fisheries (Moore and Moore, 1903). In 17th Century New England (USA), in various towns of the Cape Cod region, the alewife catch was regulated by a warden who established days for fishing and allowed only town residents to participate in the fishery (Hay, 1959).

One should not assume that these "indigenous" assertions of property rights in the preceding examples necessarily became a thing of the past with the advent of colonialism, and particularly with the coming of colonialism's new doctrine, "the freedom of the seas". Indeed, indigenous systems of property rights and limited entry in fisheries are very much with us today.

In the Philippines, for example, prime sites for fish corrals - some of which were owned and administered by the Tagalog chiefs in pre-colonial times and which, during the colonial era, were controlled by Spanish colonial authorities - are now owned and administered by the municipal governments in their regions, even though most other coastal and offshore fishing grounds in the Philippines have long since become common-property resources (Spoehr, 1980). Furthermore, in south coastal India, villages still assert property rights over particular fishing grounds, even though technically these fisheries too are common-property resources (Norr, 1972). In diverse parts of Oceania, traditional, pre-colonial systems of marine-resource management - particularly those conferring property rights and prescribing limited entry into certain fisheries - are now being reinstitutionalized (Johannes, 1978).

Brox (1964) notes that the assumption of rights to marine territories and resources through mechanisms such as inheritance and marriage are still in effect in parts of northern Norway. Andersen (1976) discusses how small-scale (handline) artisanal fishermen of Bermuda have a system of "positional tenure" over shallow-water fishing areas, particularly those areas they have recently baited.

Just how fishermen and fishing communities enforce their property rights presents an interesting array of behaviour. Probably one of the most interesting means is through extralegal (i.e. illegal)

assertion of rights, that is, the assertion of rights, exclusive access, etc., in a manner contrary to formally established legal regimes of a central authority, and often in fisheries which are otherwise legally considered common property. As Andersen (1982) states, the "development of public, legally enacted management schemes often does not stop the exercise of indigenous strategies for self-regulation, not even when the new legal managerial regimes render the indigenous strategies illegal".

Similarly, Acheson (1972, 1975, 1979 and 1982), in a number of interesting accounts all discussing the indigenous management system employed in Maine lobster fisheries, highlights how extralegal regulatory measures supersede the regulatory regime of the state, which officially asserts the fishery is a common-property resource. Although technically the Maine lobster fisheries are a common property and anybody wishing to fish in them has a legal right to do so, so long as he purchases the necessary licence and abides by various laws and regulations, in actual practice entry into the fishery by an "outsider" would be extremely difficult. In the Maine lobster fishery, each harbour has a "harbour gang" composed of community members who mutually recognize each other's right to work in the fishery. Entry into a harbour gang basically only comes about through birth and/or long-term residence in the community, kinship with a harbour-gang member, starting out while young and not starting out too ambitiously. Furthermore, each harbour gang asserts exclusive rights of access to a fishing territory associated with its harbour. This territory has more or less definite bounds, although it may overlay with the territories of other harbour gangs at some distance from home port.

Interlopers who intrude into a harbour-gang's territory risk reprisal in various forms: everything from verbal or physical abuse to loss and/or destruction of their gear. Thus, each harbour gang along the Maine coast asserts common ownership and exclusive access to the lobster-fishing territory associated with its harbour.

A similar state of affairs is reported by Andersen (1982), who notes that small-scale fishermen from villages along the Newfoundland coast exercise various extralegal sanctions against outsiders encroaching in what they assert are their exclusive territories. Again, these sanctions range through verbal abuse and "sheer aggressive dominance" to such measures as cutting away the trawl lines of interlopers.

Pi-Sunyer (1977) records an instance in which artisanal fishermen in Spain physically barred large vessels from landing their catches in their town. In 1979, artisanal fishermen from Goa, India, after suffering years of declining catches in their traditional coastal fishing grounds because of the incursion of industrial-scale trawlers, eventually took matters into their own hands, seizing two trawlers and setting them on fire, a move which undoubtedly diminished trawling effort in their region (Osamu et al., 1979).

This author has also observed various instances of extralegal assertion of property or territorial rights, or rights of exclusive access, in certain fisheries of concern to artisanal-peasant fishermen in rural pacific Mexico. The entry of new middlemen (marketeers) is particularly discouraged in various rural villages, with sanctions ranging from verbal abuse to sabotage and violence. The entry of outside middlemen is also effectively discouraged by local middlemen's practice of "tying up" the catches of local fishermen through the ages-old system of debt peonage. Furthermore, sabotaging and stealing gear set by fishermen from neighbouring villages, who have set their gear in territories that a particular village (extralegally) asserts is reserved for itself, sometimes occurs. Although national-governmental laws have set aside formerly traditional fishing grounds for the exclusive use of local fishing cooperatives, impoverished fishermen who are not members of those organizations openly fish in the cooperatives' reserved territories, and more than once have committed violent acts against governmental agents dispatched to such areas for purposes of enforcement (McGoodwin, 1980). Furthermore, prior to Mexico's assertion of its exclusive economic zone out to 200 miles, foreign longliners often set their lines fairly close to the Pacific coast and artisanal shark fishermen I have studied for years have often shown me such gear they took for themselves, stating they took whatever gear they encountered, both to save on gear costs and also to reserve resources for themselves.

The exclusion of "outsiders" is thus a very common strategy in indigenous systems of fisheries management, and methods for excluding them range from definition of the "in" or member group, through schemes of informational management to acts of sabotage, verbal abuse, and/or physical violence.

Among small-scale oyster fishermen in a rural community on Apalachicola Bay, Florida (USA), kinship ties define possible participants in the fishery. This community exhibits a type of insularity or "clannishness" typical of many rural fishing communities throughout the world (Rockwood et al., 1973), and similar observations come from diverse other small fishing communities; in Newfoundland (Andersen, 1979 and 1982; Martin, 1979), Maine (Acheson, 1979), Sweden (Lofgren, 1982), north-western Washington (Suttles, 1974), and Oceania (Johannes, 1978).

A number of researchers have commented upon how systems of informational management also may serve to spatially separate fishermen, exclude others from a fishery, or effectively limit their effort (Acheson, 1981; Forman, 1967 and 1970; McCay, 1981). Fishermen often form alliances - "code groups", for example - in which a sub-set of the total number of fishermen engaged in a fishery share information while otherwise denying important information to other fishermen not part of their alliance (Orbach, 1977; Stuster, 1976 and 1978). Various writers have urged that information management, particularly that which maintains secrecy about good fishing spots, confers a temporary, defacto property right upon those having the information (Forman, 1967 and 1970; Lofgren, 1972; Stuster, 1978). Andersen (1972) speaks of how "informational capital" is concentrated in patrilineally-related fishing groups of small-scale fishermen in Newfoundland. These, he states, employ a diversity of strategies of informational management: e.g. hoarding information on especially good fishing locations, giving misleading information to others - mainly in the form of under-statement - in order to lead them away and/or cause them to waste time and effort, or not landing all of one's catch at any one time or place in order to understate its extent.

Kottak (1966), discussing artisanal fishermen at Arembepe, Brazil explains that, while fishermen there view the sea as an open-access resource, they keep information about good spots secret.

Informational management of this type is elaborately discussed in two well-known studies by Forman (1967, 1970). In his description of artisanal raft fishermen who fish along the Brazilian coast, he explains that these view the fishery as an open-access, common-property resource. Information concerning good fishing grounds among these fishermen is more or less common knowledge, while information concerning particularly good spots within these grounds is a highly guarded secret. The common knowledge of good grounds, he argues, guarantees at least moderate success for everybody, while the secret knowledge about particularly good spots prevents excessive competition around these.

Similarly, discussing the value of information-management systems in artisanal fisheries, Cordell (1974) describes a complex system of knowledge employed by inshore artisanal fishermen working in an estuarine region of Brazil and laments that the loss of this knowledge through the demise of their traditional fishing systems will be a serious loss for the science of fisheries management, since these systems encode and are based upon years of accumulated experience in that particular marine ecosystem. He further states, however, that he is not certain whether these fishermen's specialized knowledge is a definite factor preventing over-harvesting, since most of them eventually learn the system. I will return to the matter of the salience of these and other methods for excluding or limiting "outsiders" in the final paragraphs of this section.

In my own research in Pacific Mexico, I have recorded a marked contextual difference in informational management among that region's artisanal fishermen. Basically, what I have observed is a greater tendency for secrecy and giving misleading information while fishing inshore waters and a practically opposite sort of behaviour - i.e. cooperative sharing of information - while fishing offshore (McGoodwin, 1979). This brings to mind Cordell's observation, that most traditional inshore fisheries are inherently "fixed-territorial" in nature, necessitating relatively greater regulation of specific spaces, than is the case with fishing offshore (Cordell, 1978). This observation, incidentally, is congruent with Andersen's (1982) observation that offshore Newfoundland fishermen show a greater desire for limiting effort in harvesting pelagic, as opposed to demersal species, feeling fishing activity has a greater tendency to disturb pelagic species. McCay (1981) similarly observes less tendency to limit effort on migratory as opposed to more fixed-territorial resources. A general conclusion thus arises, that the more confined, territorially limited, immobile, or vulnerable the resource is to being disturbed, the greater will be the tendency on the part of fishermen to create mechanisms for limiting fishing effort on that resource. Indeed, it is now generally accepted that, as a fishery becomes highly pressured, rights of access are usually the first and most fundamental aspect of any innovations in its managerial regime.

A number of researchers studying aspects of self-regulation in fisheries have argued that skill differences may be far more important in limiting productivity than any differences in effort per se (Acheson, 1977 and 1981; Andersen, 1973 and 1979; Cordell, 1974; Forman, 1967). Differences in skill imply differential access to information, and the reluctance of fishermen to share information concerning skills has been widely observed (e.g. Acheson, 1977; Andersen, 1980; Drucker, 1965; Farris, 1972; Forman, 1970; Nemec, 1972; Paine, 1957). One of the astounding observations of this author during early field studies in Pacific Mexico was to note the great differences in fish harvested by various fishermen from the same village. Much of the difference could be attributed to differential knowledge of special spots, but one particularly amazing observation was to note great differences in yield among fishermen all fishing at the same spot, and using the same methods, bait, gear, etc.

Some other interesting methods for regulating access to fishing space merit mention here: basically, various forms of fishing etiquette, such as taking turns or honouring first-come, first-served at a fishing spot where the number of fishermen desiring to exploit it greatly exceeds the availability of fishing space (see examples in Britan, 1979; Cordell, 1978; Catarinussi, 1973; Orbach, 1977; Alexander, 1977). In his account concerning artisanal beach-seine fishermen in southern Sri Lanka, Alexander (1977) describes a rather elaborate system of taking turns in the deployment of a relatively large number of beach seines in a limited number of good spots. While the Sri Lanka fishermen perceive their fishery as an open-access, common-property resource, they are also aware that chaotic competition would ensue if all groups owning beach seines competed simultaneously for the limited number of good fishing spots. Hence, their local society has developed a system of taking turns based, according to Alexander, upon "the moral principle ... of equal opportunity". Similarly, artisanal net fishermen in a crowded, inshore-Brazilian fishery described by Cordell (1978), employ a complex system for asserting at least temporary property rights at prime fishing spaces: e.g. spacing, if possible; honouring the principle of first-come, first-served; or, if a number of fishermen arrive simultaneously at a good site, then lots are drawn to determine the order in which they will get to shoot their nets. Andersen (1982) also discussed analogous sytems of internal management which were formerly employed by small-scale, traditional fishermen in Newfoundland: e.g. "gentlemen's agreements" and holding drawings for named sites for placing cod traps.

Assertion of property rights - whether through legal or extra-legal means, informational management or mechanisms of "etiquette", etc. - are only the main methods by which fishermen attempt to control fishing space. Certainly, concerted political activism is another important method employed for achieving that aim.

I mention political activism in a singular context in order to counter the often heard ideas that most small-scale fishermen are not politically inclined, are rugged individualists, are not particularly given to cooperative action or, because of the linearity of coastlines, they are naturally isolated from one another, making concerted political action difficult (Nishimura, 1973; Hewes, 1948; discussion such characteristics in fishermen's cultures). Nonetheless, in many instances small-scale fishermen have taken politically effective action - both legal and extralegal - in order to secure exclusive or preferential access to fishing space. The formation of fishing cooperatives, for instance, is probably the best example of effective political action, with too many cases to mention here. However, in the following I will mention a number of noteworthy examples of politically effective action (other than cooperative formation) having importance in this discussion of self-regulation in fisheries.

Pi-Sunyer (1976) notes a case in which small-scale fishermen in Spain were effective in barring a yacht club from building on what was traditionally the fishermen's beach. The importance of the beach to the local fishermen was more symbolic - a matter of their history and traditions - than it was economic by the time the controversy arose. Nevertheless, the fishermen took their case to the central government and won a judgement in their favour.

Thomson (1980) reports an instance in which gillnet and driftnet fishermen in North Yemen's Red Sea fisheries, after suffering years of depradations by large-scale trawlers which had entered their traditional fishing grounds, politically organized and got their central government to withdraw permission for the trawlers to operate there. Furthermore, in another case reported by Thomson (1980), small-scale fishermen in the Malacca and Bali Straits, East Java, Indonesia, who had suffered similar depradations of their traditional fishing grounds due to the efforts of trawlers and purse seiners, were influential in securing a governmental decree stating that they (i.e. the artisanal fishermen) would be the priority group in Indonesia's future fishery-development programmes.

These are not mere isolated examples. Throughout the world small-scale fishermen are becoming less isolated, owing to advances in communications and transportation, and also more politically aware. Gradually also, their significant contributions to their national cultures is becoming more widely understood. Increasingly, in a variety of important fishing regions, they are becoming successful in getting legal frameworks established which limit access to their fishing grounds (Andersen, 1974; Charest, 1979; Johannes, 1978; Klee, 1980; Martin, 1979; Osamu et al., 1979).

Control of fishing space, while perhaps the major means of self-regulation in unmanaged fisheries, is not the only means of importance. The practice of biologically sound conservationist principles has also been widely recorded in a number of indigenous systems of fisheries management. Johannes (1978), for example, states that "Almost every basic fisheries conservation measure developed in the west was in use in the tropical Pacific centuries ago". These measures included closed seasons, banning fishing during spawning periods, allowing a portion of the catch to escape, deliberately not taking all the available stock of certain species, holding excess catches in enclosures until needed, a ban on taking small individuals (particularly slow-moving or sessile organisms, though not small fish), restricting the number of traps in an area, and even avoiding the harvest of seabirds and/or their eggs, particularly species of birds which help indicate the locations of fish. "Gear restrictions" he observes, however, "probably the oldest form of fisheries regulation in the west, seem to be the rarest form of conservation in Oceania" (p.355). These observations are augmented by Klee (1980), who records the use of master fishermen in parts of Oceania in the role of "conservation officers" and "fishery ecologists". In many Micronesian fisheries, he notes, these masterfishermen were empowered with the authority to permission and/or organize fishing parties, lead communal efforts (especially turtle hunts) and restrain fishermen's efforts so as to conserve resources.

Moore and Moore (1903) write that, in 13th Century Britain, Royal Regulations governing salmon fishing in the County of Cumberland required riverine nets to be spaced far enough apart to allow some of the spawning fish to pass upstream. Such spacing was referred to as "The King's Gap".

In the aboriginal salmon fisheries of Pacific North America, the various chiefdoms there attempted to limit both effort and mortality through imposing limits on the times of day and the seasons in which harvesting activity could occur, imposing catch limits or quotas in view of needs and the removal of traps at certain times so salmon could proceed upstream. These measures were well-known features of the salmon fisheries at Celilo (near the present-day Washington-Oregon State boundary) and at Kettle Falls (near present-day Spokane, Washington). It is clear the aboriginal peoples enacted these self-regulatory measures for the conscious purpose of sustaining the resource (Walker, 1983), and one researcher in this fishery suggests they may have also allowed salmon to escape upstream in order to maintain alliances with and/or forestall the aggression of people living upstream (Hewes, 1983).

In various contemporary fisheries, fishermen have been observed to employ conservationist measures in order to sustain stocks, at least so long as access to the fishery is limited and neither dwindling yields nor chaotic competition is being experienced. Johnson (1982) has observed artisanal fishermen in Honduras returning small fish to the water so they can grow to larger size. Acheson (1982) notes that small-scale lobster fishermen in Maine impose internal restraints on their own members' fishing behaviour: e.g. directing verbal abuse at "harbour gang" members, for example, who are seen as over-zealous in their production effort (fishing in bad weather or setting too many traps) and in a few instances avoiding the use of more effective gear (metal traps), feeling it might lead to over-harvesting. Furthermore, Berleant-Schiller (1982), describing artisanal lobster divers in Barbuda in the Caribbean Sea, notes these spare gravid females and also consciously turn away from fishing activity when they feel declining yields indicate their resources are being over-harvested. In that study, the author strongly argues that the artisanal fishery meets the needs of subsistence and also redistributes money among the island's populace, while never enough money is earned to finance more mechanized modes of fishing. "So far", Berleant-Schiller states, "an interaction of environment, artisanal technology, and economy has protected the fishery from depradation and preserved it for local use", a "working balance", which could easily be upset by mechanization aimed at increasing production (p.134).

McCay (1981) also reports instances of voluntary restraint and/or application of conservationist measures on the part of clam-fishermen she studied in New Jersey. These fishermen, she recalls, state that if they did not exercise restraint they could "send the clams to the same fate as the American

buffalo" and that they selectively "thin the stocks for a better harvest". She also reports that these fishermen intentionally limit their own productivity, not only to sustain stocks but also to support or drive up their price in the marketplace.

Are indigenous methods of asserting private property, limited entry, excluding outsiders, extra-legal action, informational management, etc. effective means of fishery management? Good studies show that when fishermen have property rights there is less tendency to over-exploit marine resources (Acheson, 1975; Berkes, 1977; Johannes, 1973; McCay, 1980; Wilson, 1977). Johannes (1973), for instance, notes that in Micronesia the ownership of reef and lagoon sites by chiefs and families is today a viable means of control "except around population centres", whereas in Western Samoa and the Cook Islands, where such sites are now common property, the stocks arè over-exploited. However, a contradictory conclusion may be drawn from Andersen (1982) who notes that, while Newfoundland fishermen have been mostly successful in excluding "outsiders" from entry into their fishing grounds, they have still over-harvested their fishery. Local strategies for excluding outsiders, he concludes, have been ineffective over the long run to sustain resources. Of course, the Newfoundland fisheries have been extensively exploited for a long time, and have also been subjected to various unstabilizing forces in more recent years, such as the introduction of more effective gear and changing managerial regimes.

Concerning informational management and/or secrecy as a possibly effective strategy for fisheries management, the opinions of various researchers seem inconclusive. For example, while Forman (1967) asserts that among Brazilian raft fishermen secrecy accords temporary property rights over prime spaces, minimizes competition and prevents their over-exploitation, McCay (1978) and Cordell (1973) both caution - in essence - that quantitative substantiation is lacking to prove whether secrecy accomplishes such aims and, furthermore, it is certain that secrecy is conducing to inefficiency and wasted effort.

Summary and Conclusions

As I have shown, in the unmanaged fisheries of early, primitive, pre-colonial and/or pre-industrial humanity - fisheries which may not have employed any mechanisms for self-regulation - it was not always the case that their human inhabitants lived in a state of harmony and balance with nature. Although some instances of persisting harmony were noted - cases in which there seemed to be neither self-regulation nor over-exploitation - these cases were seen to be rare, and it seems more generally the case - particularly in fisheries where the human population has become dense and its technology highly effective - that, unless means for controlling access and effort are developed and implemented, the phenomenon known as "the tragedy of the commons" will almost inevitably arise.

Important aspects of passing self-regulation reviewed in this paper included simple inability to over-harvest, by virtue of low human population and/or technological inadequacy to over-harvest, and also the existence of plural economic systems, in which fishing is only one of a number of essential economic activities available. Also important as a means of passive control is the lower-bound phenomenon, a point at which fishermen decide fishing is no longer worth the effort and turn to other activities. Economic pluralism, it is concluded, seems a healthy, positively adaptive state of affairs in small-scale fisheries, and this observation should provide a stern warning to any who would seek to transform a pluralistic economy into one in which fishing - particularly highly-mechanized fishing - becomes the exclusive occupational activity.

Other passing restraints on fishing effort were mentioned - food taboos, religious or ritual practices, randomizing strategies, reduction of the human population devoted to fishing, etc. - all of which may be seen as possibly effective indigenous mechanisms for passive self-regulation.

Most active means of fishery regulation arising in indigenous systems of management entail limitations on access to fishing space through various means: the formal assertion of property rights and/or administrative control, exclusion of outsiders by both legal and extralegal means, information management, political activism, etc. An important point seems that localized fishermen will enact their own strategies for fisheries management, even when doing so may be illegal or even when their fisheries come under the aegis of a higher, centralized authority.

Most data-based studies having quantitative salience in the evaluation of fishery-management strategies apply to large-scale, highly industrialized modes of fishing and, although tremendous progress has been made over recent decades, most experts still agree that mathematical approaches to fisheries management are still in their infancy and are at best a very inexact science. The situation concerning the scientific management of small-scale fisheries is even less well developed, perhaps only embryonic, with very few studies now available quantitatively testing the salience of various strategies of indigenous management systems. Such studies are badly needed if we are to have informed policies for the future management of small-scale or artisanal fisheries. As Kesteven (1976) stated a few years ago, "I know of no systematic and comprehensive study of an artisanal fishery in which catch and effort have been measured, mortalities estimated, and the value obtained for the exploitation index ..." However, he does state that good data-based studies may soon be available concerning the artisanal fisheries in lagoonal Pacific Mexico, and in Puerto Rico and Jamaica. Thus, the lessons or suggestions I offer below should be taken as little better than well-informed hunches or intuitions.

Concerning the appropriate management of small-scale fisheries and fishermen, I offer the following suggestions, most of which have been deduced from the foregoing review of the various studies going into research for this paper. First, to the extent possible, future schemes for management should rely heavily upon the incorporation of indigenous strategies, especially when these seem to be effective and are in accord with accepted biological principles of fishery management; second, in many fisheries the possibility of rescinding common-property regimes should be given a high priority, with an eye toward substitution with regimes featuring limited entry. This seems particularly true in inshore and coastal fisheries - especially in any fisheries in which marine resources are basically immobile or environmentally circumscribed. Similarly, to the extent possible, these limited-entry regimes should correspond to the existing domains of both socio-cultural regions and marine eco-zones; third, as a matter of general policy, emphasis should not be placed on the retention of indigenous mechanisms of informational management (such as secrecy, etc.) nor upon gear restrictions, since both are conducive to inefficiency and wasted effort; fourth, every attempt should be made to conserve and/or revitalize subsistence-oriented effort and effort for supplying regional markets, even if this is at the expense of larger-scale and export-oriented fishing enterprise. The idea here is the creation of a sort of upper bound on productivity, which is congruent with a fishery's sustainable supply; fifth and finally, continuing emphasis should be placed upon the formation of fishermen's cooperatives and upon political activism in the service of just causes.

Note

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INDIRECT APPROACHES TO REGULATION OF FISHING EFFORT

by

J.F. Caddy
Marine Resources Service
FAO Fisheries Department

INTRODUCTION

It is a general principle of legislation and managerial action that, if a desired result can be obtained directly, it is more appropriate to frame the laws, guidelines or regulations in such a way that this objective is clear to all, rather than to achieve it by indirect means. From this viewpoint, the most obvious approaches to regulating the harvesting of a stock are either to control the level of catches or landings or to control access to the resource. These more or less direct approaches have been extensively discussed elsewhere and a fairly large body of experience has accumulated in developed countries suggesting that, although these two approaches are direct, they are also information hungry and require a large civil service for the day-to-day operations involved in collecting and processing the necessary information and in enforcing the regulations.

Bearing in mind that the ultimate control on harvesting intensity is to manipulate the level of fishing mortality exerted, it is worth asking what other types of regulatory measures can be considered that affect this important variable.

The following paper presents some of the other possible types of regulation that can indirectly affect fishing mortality on the stock, and inevitably these include many of those regulatory measures available to the manager which are not often thought of in the context of effort control. Deliberately excluded here are those socio-economic impacts that drive the fisheries system which, again, are treated elsewhere. Indirect measures can sometimes present rather effective if less quantifiable alternatives, alone or in conjunction with other measures, for controlling the fisheries system without enormous expenditures. A list of such possible measures, with their main advantages and drawbacks, is given in the following document and is intended principally as a basis for more detailed discussion during the course of the Consultation.

INDIRECT METHODS OF CONTROLING FISHING MORTALITY

Seasonal closures of fixed duration

Various reasons have been proposed for closing fisheries for limited or longer periods of the year. All of these share in common the objective of protecting the stock from exploitation during at least part of its life history or during particular seasons of high vulnerability and may enclose part or all of the range of the resource in question. Two separate types of motives may be recognized for such closures:

1. **A non-specific one: namely to maintain exploitation rates at reasonable levels if fishing effort is essentially uncontrollable**

Problems : The main difficulty is that the closed season may grow to occupy a significant part of the year, if the stock remains vulnerable and high economic returns are realized or if poor alternatives to exploitation of this resource exist. The other problem is in deciding on the duration of the season, particularly if unnoticed increases in efficiency of harvesting can occur. This may lead to calls for institutionalizing inefficient methods of harvesting, which is then likely to require greater enforcement activity unless more specific entry limitations are brought in. We may conclude that this type of measure alone is unlikely to be effective in protecting the stock or maintaining a given stock size.

Advantages : In some senses, enforcement of closures is simpler than other regulations, particularly if there are only limited points of landing; however, the rather deceptive simplicity of the legislative process may obscure problems of enforcement if the resource in question is available from other fisheries that are open at this time. In this case, possession of the catch or the fishing gear may not be an adequate basis for prosecution. This type of enforcement measure may therefore be complicated if a vigorous black market exists, especially if the product is imported legally from elsewhere during the closed season (e.g. the Caribbean spiny lobster fisheries - FAO, 1982). Seasonal closures may also lead to wide fluctuations in price and discontinuities of supply, with again the development of conditions conducive to black markets for illegal fish (example: the Canadian East Coast lobster fishery - De Wolf, 1974).

(N.B. One possible variant of fisheries closures is an institutionalized turn-around time, fixed number of trips per year or enforced layout (e.g. Crutchfield and Zellner, 1962). This type of measure, although rather weak in its potential impact, has some advantages where mechanisms already exist (e.g. customs clearance) to monitor entry and exit from port. Another variant used (particularly in certain shellfish fisheries, e.g. the Brittany scallop fishery) is a limited number of fishing hours per day in a day fishery. This appears to be taking the concept of institutionalizing economic inefficiency to an ultimate point, and also poses some obvious enforcement problems.)

2. Closures to protect life history stages, or prevent fishing during particular seasons of the year

A number of different motives for closures come into play here, of which the following is probably an incomplete list:

(a) Closures to protect the stock during periods of special vulnerability

Such vulnerable components of the population may be pre-spawning aggregations, during spawning or seasonal migrations through areas of high vulnerability, i.e. so-called "gantlet" fisheries (Paulik and Greenaugh, 1966; Caddy, 1982). This type of closure can apply to all types of gear or (as with fixed gear during migration of anadromous fish) just to the more efficient or "destructive" type of gear.

Problems : In many fisheries, particularly for those where spawning is inshore, harvesting during the spawning season is often the most cost-effective procedure and application of such a regulation may prevent particular products (e.g. eggs or roe) from being harvested. Weighed against this should be the effectiveness of determining a preset "escapement" of spawners to replenish the stock. One approach to this problem may be to allow fishing only on certain days of the week, if this can be done without interrupting spawning or damaging the deposited eggs.

(b) Closures during periods of poor market prices or when condition of the fish is poor

For species where the level of seasonal landings strongly dictates market prices or where the species is less valuable because it is in poorer marketable condition at certain times of year, this type of regulation, if applied judiciously, can do a great deal to improve economic returns for the same landed weight.

Examples : Illustrative of the first case is the Southwest Nova Scotia lobster fishery where the winter open season coincides with low abundance and high prices for this product on the North American market, since most of the landings elsewhere on the east coast of North America are taken during summer months of high vulnerability to trap fishing in the New England lobster fishery that effectively dominates the market (De Wolf, 1974). This is also an example of the second category of measures above, since winter seasons for northern lobster coincide with optimal quality and handling conditions, with few of the soft-shelled (post-moult) specimens occurring that are so common in summer.

(c) Closures because of seasonal toxicity or unpalatability of the product

Seasonal closures, e.g. of shellfish fisheries due to paralytic shellfish poisoning (PSP) or because of high coliform counts, may in some parts of the world have an indirect impact in assisting conservation, although this is unlikely to be more than marginal in most cases.

General comments on (a) to (c): It has largely proved impossible to control exploitation effectively by this type of mechanism even though in most cases enforcement of seasonal closures is easier than, for example, quota management.

Seasonal closures of variable duration

Theoretically, varying the duration of a fishery may under certain conditions provide some control of the level of removals or at least the minimum biomass to be left at the end of the season for reproduction of the stock in the following years. (A distinction is made here between the situation where the season is preset but its duration may be varied from year to year, depending on the number of units in the fishery, and a situation where the season length is not set in advance but may be closed at such time as a particular set of criteria are met.)

Two approaches to stock assessment underlie this approach: the Leslie-Delury methods of estimation (Ricker, 1975); both of which require that the stock remains constantly vulnerable to fishing during a given season without excessive immigration or emigration (Fig. 1).

Both models have been used to estimate fish population size but can be modified to provide the basis for a regulatory mechanism, if the above criteria (no immigration/emigration and constant catchability during the season) are approximately satisfied and if catch rate and either total landings or total days fished can be monitored. Ideal circumstances for applying the approach are fisheries on relatively sedentary (e.g. shellfish) stocks, from one or two main ports of landing where complete statistics can be collected.

Various pre-agreed approaches can be used to decide on the cut-off point for the end of the season: this can be determined when the weekly or bi-weekly average catch rate falls below a given minimum pre-agreed with the fishermen. This minimum can either correspond to the predetermined economic break-even point for the fleet or be based on a desire to leave an adequate minimum biomass for reproduction. This approach has the advantage that low catch rates at the end of the season provide less incentive for infringement.

Problems: The past history of the seasonal evolution of catch rates must indicate that wild fluctuations in the availability and mean catch rate do not occur. The method also requires an efficient and timely reporting and summarization of catch rate data, and issuance of a closure notice well enough in advance to allow planning of fishing at least one week ahead. Very good communiction with fishermen is presupposed, plus strong input of fishermen to the management process.

A variation of this approach has been suggested in cases (e.g. the Red Sea fishery for cuttlefish - Sanders, 1981) where, in past seasons, a good correlation has been found between early season catch rate and total landings during the season. Using this approach, if a steady decline in average catch rates regularly occurred in the past, an in-season quota may be calculated after the first few weeks that will effectively control the effort exerted and duration of the fishery to fit whatever objectives are set by management and industry.

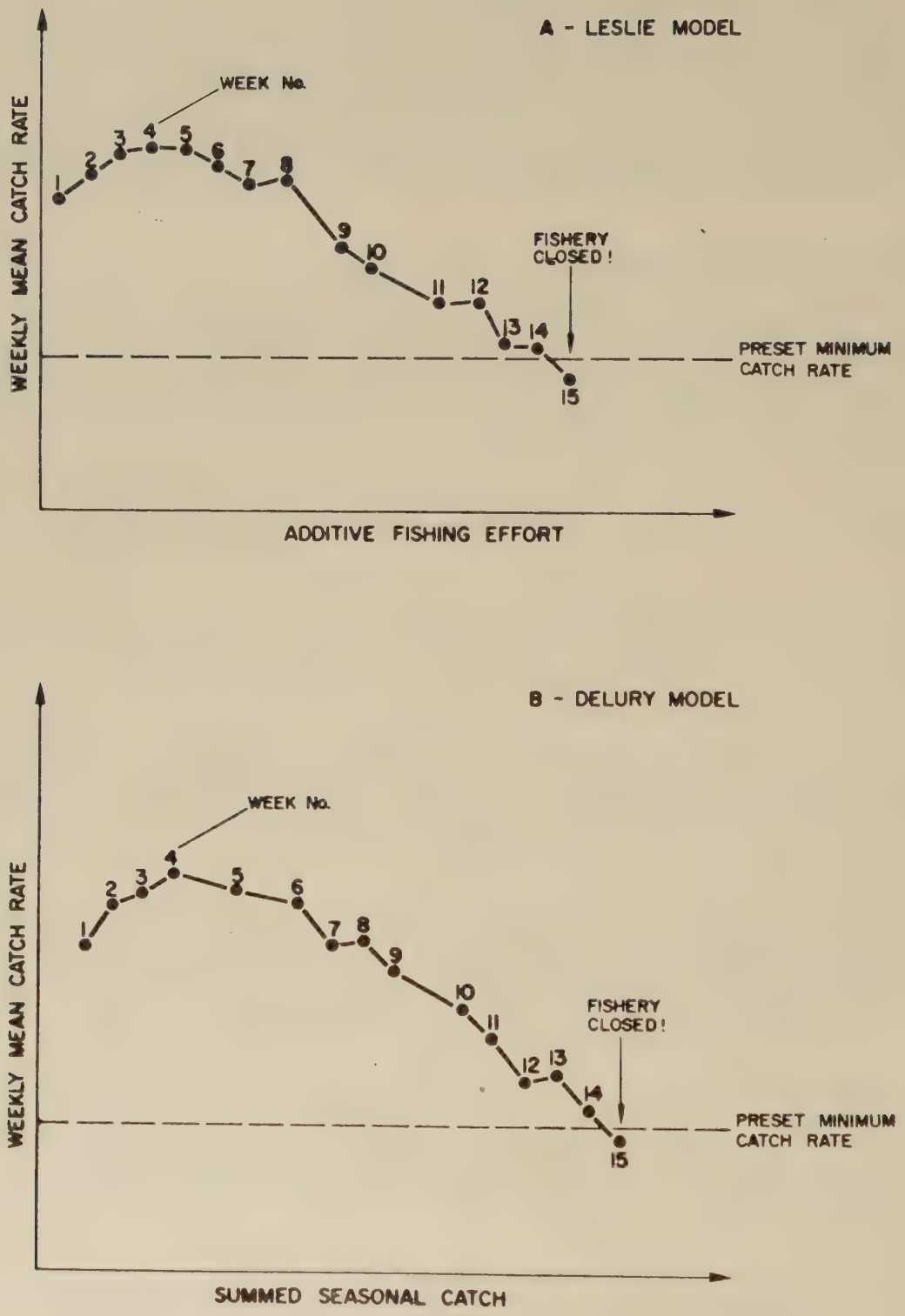

Figure 1

Two approaches to controlling effort indirectly by a variable season duration

Closed areas

In contradistinction to the preceding category of management measures, we refer here to permanent closures of small fractions of the range of a resource.

This may include:

(a) Areas of continued high vulnerability of life history stages or areas that it is not economically or biologically desirable to harvest for species where the breeding and hatching season is protracted. A possibility here might be closure of some coastal lagoons which are nursery areas for shrimp or marine fish or beaches which are nesting areas for, e.g. marine turtles.

(b) Parks or reserves intended to protect certain limited fractions of the population in areas which are heavily fished or otherwise liable to extinction, e.g. the "parcs" set aside for the "common" lobster, Homarus vulgaris, along the French coast, and certain coral reef areas now forming underwater reserves.

Advantages and problems : Although this type of regulatory measure has certain advantages in that, once instituted, it requires little subsequent attention from a legislative point of view, its effectiveness in ensuring survival and re-seeding of adjacent depleted areas is often difficult to evaluate. Problems of enforcement may also be expensive and, even if a majority of fishermen are in agreement with the measure, the possibility of infringements by a few individuals will need to be monitored.

The effectiveness of this measure as a source of replenishment for the population elsewhere in its range will depend on the area chosen, its size and whether it protects some or all of the life history stages of the population. Evidently, if the area is too small to contain a viable breeding population, the value of such parks or refuges must be questioned. In the case of species with pelagic larvae, the refuge should be "upstream" from commercial areas with respect to prevailing currents and should coincide with the known distributional range of mature individuals.

Refugia

This term has come to have rather wider connotations than simply a limited area where harvesting is forbidden (see Anthony and Caddy, 1980). A refugium may be any set of circumstances, geographic of otherwise, that ensures that a certain (limited) proportion of the population survives to breed. Some obvious examples are as follows:

(1) Limited occurrences of locally poisonous (e.g. ciguatoxic) fish have become known to fishermen, in several tropical and sub-tropical areas of the globe where this type of phenomenon occurs, and result in normally palatable fish (e.g. groupers and snappers) being unsafe for human consumption (Olsen et al., 1983). The low fishing pressure exerted locally in these areas may preserve breeding populations that will provide non-toxic recruits to adjacent heavily-fished "safe" areas.

(2) Sub-tidal populations of valuable resources (e.g. abalone, lobster) may be fished to low levels in absence of effective regulations but the marginal fringes of such populations (or areas where, because of e.g. strong currents, harvesting is limited) may constitute refugia for the species.

(3) A similar situation may prevail in trawl fisheries for species where a proportion of the stock occupying untrawlable areas constitutes a refugium for the species.

(4) More subtle types of refugia may be provided by fishing methods. For example, the maximum diameter of trap aperture for lobster pots or fish traps constitutes a refugium for those individuals that survive to a size too large to enter a trap. Alternatively, the limited depth of action or range of fishing vessels can constitute a refugium if only part of the range of the stock is covered.

(5) A special category of regulations relevant here are the "maximum size" regulations that are in effect for lobster in Maine, USA, and the "berried" lobster law in Canada that prohibits possession of large females bearing eggs. Similar maximum size regulations have been proposed for sturgeon where large females contribute a great proportion of the mature eggs.

(6) Setting fishing seasons, during seasons when weather conditions are too rough to fish in certain parts of the population range, is in effect providing a refugium.

Comment : This type of management measure previously was achieved incidentally, and was very effective in the early stages of fisheries (especially primitive artisanal fisheries) that initially only exploited a fringe of a population residing in generally deeper waters, but is rarer now that fishing boats and gear are more efficient and can fish at greater depth. Theoretically, formulating regulations to ensure fixed escapement would be possible if a certain proportion of the total range of the stock were left unfished, as with the concept of periodically fallow land in agricultural crop-rotation practices. One possible indirect benefit of fisheries closing zones or EEZ boundaries would result if regulations were formulated to ensure that areas within a limited distance of a maritime boundary were not fished, as in fact happens nowadays close to underwater pipelines or oil rigs. With growing use of the marine environment, and a greater awareness of property rights and their boundaries, we may suspect that the creation of such marginal refugia may grow in importance, even though it is very difficult to consider them as a principal method of management.

Coastal belts

The concept of a coastal fringe reserved for inshore or artisanal boats and closed to large industrial (e.g. trawler) fleets has been put forward in a number of forms in several countries, based either on a minimum distance from shore or minimum depth of operation of the offshore fleet. Maximum depth or distance from shore is rarely specified for the inshore fleet component, reflecting a socio-political decision to reserve certain benefits for coastal communities and especially artisanal fishermen.

One factor enhancing the attractiveness of this type of regulation for many tropical nearshore fisheries is the relatively narrow depth range of the shallow shelf supporting fisheries with a high productivity. This makes it necessary for trawlers to fish closer inshore than in temperate regions, which again leads to the kind of conflicts that promote this kind of regulation.

Although the motive for this type of regulation is usually past overfishing of nearshore areas by industrial vessels, its immediate objective is often the reduction of gear and vessel conflicts between different national fleets. Initially, this measure will have an indirect impact on the total fishing mortality exerted on nearshore stocks, but this will not necessarily persist unless supplemented by other regulations governing individual access or limiting levels of removals.

Advantages and problems : Although there is one clear political advantage to this type of action, in that there are usually larger numbers of individuals involved in the artisanal fishery than in the industrial one, evaluating the impact of this type of regulation is not so easy. For example, it must be considered whether or not the main resource is migratory and can still be fished offshore. If so, under certain circumstances, the offshore fleet may continue to control catch rates of the inshore fleet if specific offshore allocations are not given. Conversely, if artisanal fleets exploit such shared stocks on the nursery grounds (e.g. for penaeid shrimp), they may control recruitment of adults to the offshore grounds where they could otherwise have been caught at sizes providing a greater economic yield. Unless enforcement is left to the fishermen, this type of measure doubles the length of maritime boundaries that need patrolling (i.e. the boundary of the coastal belt is added to the EEZ boundaries).

Size limits and effort control

It has been noted that regulations that restrict the size of the fish caught directly, or via regulations on the minimum mesh size of the gear, act indirectly to restrict the fishing effort exerted on certain components of the stock, particularly on the younger and smaller fish. This is especially

obvious for species such as squid and penaeid shrimp which usually have a population consisting of one year class and where an increase in mesh size in effects acts as a closure, thus delaying onset of the fishery. Also, for multi-age stocks, areas of congregation of schools of young fish may be protected from heavy fishing by appropriate mesh sizes or the fishery postponed, assuming of course that the stock has already been recruited to the fishing ground at this time. We can therefore conclude that size limits and other regulations do act as indirect controllers of the fishing mortality, as well as modulating the impact of the fishing effort exerted. We may, consequently, ask the question:

Under what circumstances is a minimum size regulation a substitute for controlling fishing effort?

Judging from experience in the North Atlantic Fisheries Commissions, ICNAF and NEAFC, where for many years mesh size regulations were the only ones "on the books", we can perhaps conclude that this type of measure alone does not achieve the necessary impact since, with unlimited entry, it still managed to result in decimation of some of the fisheries in question. It would be fairer however to refer to Fig. 2, showing a yield per recruit isopleth for a typical North Sea plaice stock, before attempting to answer the above question. In this figure, yield per recruit is shown by the individual "onion leafs" on a graph in which the age at first capture is the vertical, and the fishing intensity mortality rate the horizontal axis.

The maximum yield per recruit for a given size at first capture is shown by the dotted line A-A' and the maximum yield per recruit for a given level of effort by dotted line B-B' and in both cases this shows that, as a fishery is more intensively fished, the appropriate size limit needed to maximize yield from a given number of recruits must go up. Perhaps it was the failure to recognize this and adjust for it, rather than the failure of size limits in an absolute sense, that led to the situations described above. Certainly mesh size regulations alone, unless set rather too large to be practical or modified continually, will not guarantee conservation without some entry restrictions.

Under what circumstances of size at first capture then can we consider that a stock is particularly vulnerable to overfishing? Here we should look at the age of maturity and reproduction. Suppose, as in Fig. 2, a species is first fished at 8 years of age ($t'_c = 8$), but one stock A matures only at age 11, and another C at age 5; clearly stock A is more vulnerable to overfishing before spawning than is stock C which matures and breeds three years before being fished. This is obviously a hypothetical case, since the growth and mortality rates for the two stocks would be sufficiently different in this case that the yield isopleth itself would change. It is simply intended to illustrate that the need for effort control is most pressing when the stock is very vulnerable to fishing as juveniles and where mesh size regulations to protect them are not feasible.

Regulations based on mean size of fish landed or on maximum count per landed weight

This type of regulation is a feasible alternative to mesh size and absolute minimum size regulations, and may be considered as having an indirect impact on effort exerted. It may be applied under circumstances such that:

a) Large numbers of small individuals are captured by unselective gear (e.g. dredges), making an absolute minimum size limit unenforceable, and where mechanical or manual sorting of the catch is unfeasible.

b) Although the gear is unselective, the species in question is either fairly well segregated by size in areas known to the fishermen or survival of discarded small individuals at sea is known to be high (as, e.g. with shellfish populations).

Advantages and drawbacks: This type of regulatory measure is designed, as with mesh regulations and minimum size limits described earlier, to increase the mean age of capture of the species and protect new recruits from premature exploitation. In some circumstances, it can also act as an indirect measure of effort control. This latter effect comes into play as the mean size of fishable individuals in the population declines towards the legislated minimum mean size, when the effort needed to achieve a given increment in landings goes up exponentially, since more and more time and effort has to be spent culling out small individuals or looking for increasingly scarce larger individuals to bring up the mean size of the catch. This kind of regulation may, in this way, promote the fishing of marginal areas where large individuals often occur at low density, and thus has an impact in reducing effort on areas of abundant new recruits.

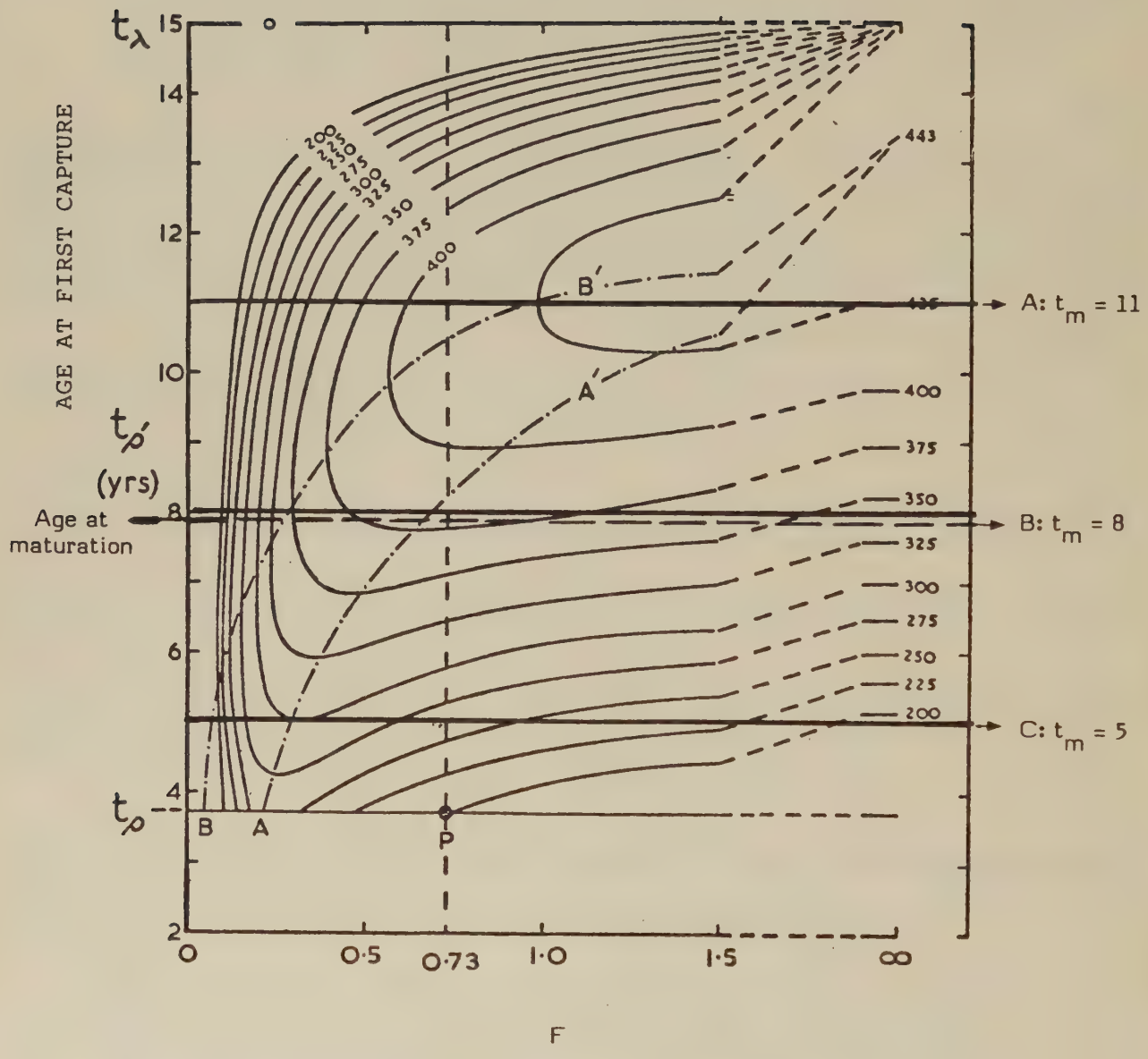

Figure 2 Yield isopleth showing combined effect of age at first capture ($t_{\rho'}$) and fishing intensity (F), on yield per recruit (from Beverton and Holt, 1956), showing a postulated age at recruitment of 8 years and 3 equally hypothetical ages at female maturity of 5, 8 and 11 years.

Since, unlike minimum size limits, some smaller individuals are landed legally, this approach is less efficient from a yield per recruit point of view, but may have some economic advantages where different size grades are needed for specific market sectors.

Specific contraindications to the use of this approach prevail where excessive discarding promotes wastage and high incidental death rates. Some difficulties may be encountered also if tolerances for infringement of the regulation are not preset, or a proper sampling procedure set up for inspection, and we can note here that the sampling procedure used may have a significant impact on the "tightness" and fairness with which the regulation is enforced.

In general, we may note that mean size in some circumstances is an index of fishing intensity or mortality and can be used as a control variable to follow changes in fishing intensity if effort is not readily measurable. In fact recent developments of production model theory (Csirke and Caddy, in press) would permit a regulatory scheme of this kind in the absence of collection of effort data.

By-catch regulations

Under certain circumstances, where a fishery is aimed at a high value species and where a significant over-investment in vessels and fleet capacity prevails (e.g. many industrial shrimp fisheries), regulations requiring that a given tonnage or proportion of hold space be devoted to bringing back edible by-catch species, will have some impact in either discouraging excessive further investment in this fishery, increasing the proportion of fishing time devoted to culling the catch, or reducing the time spent fishing specifically for the target species. This type of regulation will however be largely determined by other factors, such as the need to avoid wastage of protein.

INFORMATION NEEDS AND THE DECISION PROCESS IN FISHERIES MANAGEMENT

Fisheries managers utilize a great variety of types of information in their work, and usually have to rely on incomplete data before making decisions that will be crucial to the livelihoods of many people. As such, data collection, or a statistical service plays a key role in a fisheries department, both in relation to assessing the state of the resource and in relation to monitoring markets and available plants and vessels in the fishery. In consequence, fisheries managers have a vested interest in improving their data sources but (and this must apply particularly to managers in developing countries) they must look for data sources that are within the budget and manpower allocation available to them, i.e. the most effective and reliable sources of data (and of course the cheapest and most effective management measures they support), since these will be of the greatest utility.

Types of data

In general, at least for day-to-day decision-making, managers tend to rely most immediately on their own observations and on the opinions of trusted colleagues and knowledgeable persons in the industry. For quantitative information related for example to the level of landings from the fishery, market conditions and prices, however, an objective system of collecting data is advisable. In this situation there are at least two separate types of information which we may call "extensive" and "intensive". We may choose as examples of the former the total level of removals from the fishery or the total number of days fished by the fleet and, for the latter, the catch rate or the mean size of fish landed by a sample fleet. Although it is important for this second category of intensive indices that we know that the vessels sampled adequately represent the fleet and are not showing anomalous behaviour, we do not have to know the landings for all the boats throughout the year (which we would need for a recording system based on census techniques) nor do we have to enumerate all of the vessels fishing, as we would have to do in order to monitor landings by, for example, a sample survey.

It seems therefore that there are real advantages to measurement of intensive types of information and among these we can include catch rate, mean size and the species composition of the catch.

From each of these it may be possible to make reasonable deductions about the state of the resource and the intensity of fishing, without having complete knowledge of the removals, the fleet size or total number of days fished, and we can then take appropriate management action on this basis.

It is generally known that the mean size of a given species of fish landed decreases with the intensity of fishing, as does the catch rate. In some circumstances, a decline in the relative abundance of a given species on the market may also be a useful index of its relative abundance in the sea (Fig. 3). All of these indices have their cautionary sides, in that a low mean size may also be an index of unusually good recruitment and a high mean size may conversely indicate that recruitment failure has occured! Despite this, it would be relatively easy in many species to distinguish between low mean size due to high recruitment (in which case catch rate is likely to be above-average) and one which is due to a generally low abundance of all sizes and especially of large fish.

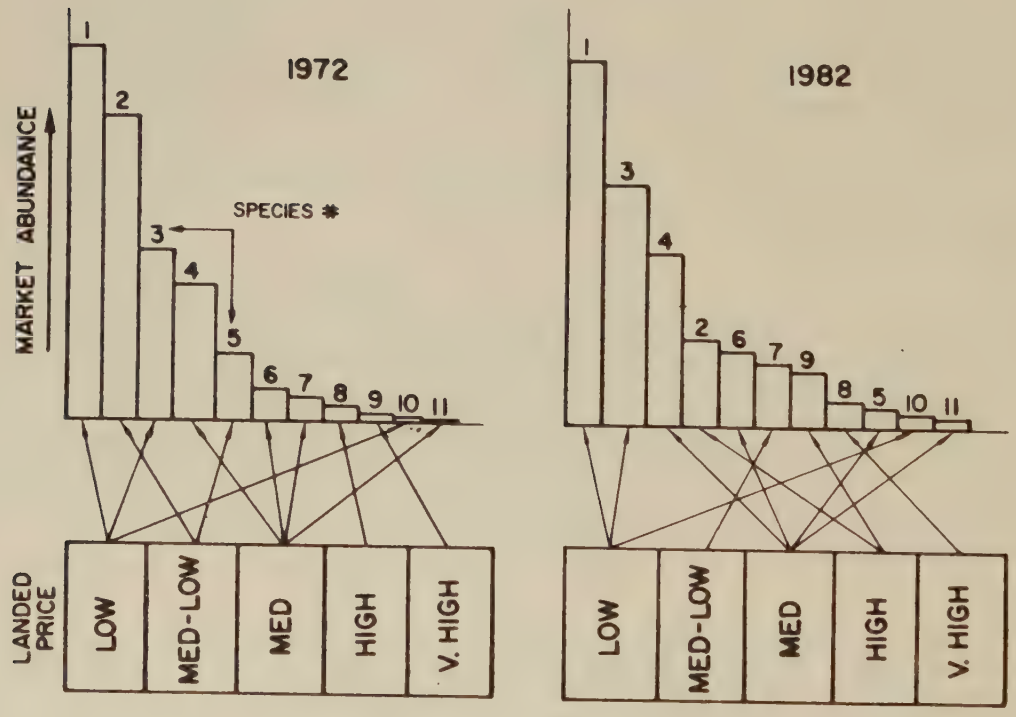

Figure 3 Illustrating how market surveys carried out in the same location in two successive periods may be used to point to possible problem areas for conservation. A decline in absolute abundance and ranked position in terms of abundance on the market for species 2 and 5, associated in this example with a movement "up-market" in terms of price, may give the manager reason to suspect a decline in abundance. If this is confirmed by further investigation, the stage may be set for some management action, controlling directly or indirectly the fishing mortality exerted on the stock.

Types of decisions

Three types of decisions may be distinguished in the managerial framework, the first two of which perhaps can be described most simply as corresponding to the mathematical signs = and or (less than or equal to, or greater than or equal to).

Attempting to manage for a given level of effort or removals, e.g. f_{opt}, $F_{0.1}$, MSY, MEY, etc., all require the manager to aim for a specific target, avoiding too high or too low values for the target variable. This is in effect aiming for equality (=) to some preset objective, and assumes that you know how to get there.

The second type of decision essentially is taken when the control variable (e.g. catch rate, mean size landed, individual earnings, market price, etc.) is either too low or too high, and involves deciding only on the direction in which these variables should be moved and not the precise position. If there are guidelines which tell you how to influence the direction of the control variable but not precisely the impact of the given manipulation, it is possible then to move in a series of discontinuous arbitrary steps in the direction recommended, pausing regularly to observe the effects of management actions on the control variable, without actually attempting to define the precise impact of any move in advance of the action. This type of decision-making appears more appropriate in basically uncertain situations such as fisheries than the former mode, since there is rarely good enough information to provide a precise "fix" on the present situation, and it is particularly relevent for assessing indirect impacts of regulations as discussed here.

The third type of decision is the null decision, which may be the most appropriate in many cases. It can however be very difficult to take a decision to do nothing to change the present situation, in view of pressure from interested parties. Generally speaking, although some events happen very rapidly in fisheries, the major decisions (e.g. on the level of fleet size appropriate to a given fishery) have long term impacts, perhaps in some cases almost as long term as the average life span of vessels and processing plants. As such, a decision not to increase for example the fleet size, until clear information is provided by the control variables that the present situation corresponds to underexploitation, may need to be sustained for periods of several years or more.

Multi-species extensions of indirect effort control

Most of the methods of effort control described so far in this document, as well as those that are considered in the other Panels of the Consultation, have implications for other than the "target" species in the catch. An example of this has already been given for a by-catch species but some more general comments are perhaps appropriate. The point being made in the following section is that, for very diverse multi-species fisheries, the proportion of a species in the catch may be as good an indication of the effect of fishing as mean size or catch rate.

First, the concept of a "target" species, which is the main species sought, may be rather irrelevant in the case of many tropical fisheries where a wide variety of species occur and where a variety of gear types operate, with often overlapping species retentions (e.g. Fig. 4). Perhaps it is then more appropriate to talk about "control" or "key" species that either occupy an important role as multi-species predators (e.g. groupers) or multi-predator preys (e.g. clupeids), or species which are taken in a wide mixture of gears (e.g. lane snappers or rainbow runners in Fig. 4). Looking at the impact of effort, or measuring mortality, on these key species may give some perspectives on what is happening to the whole community.

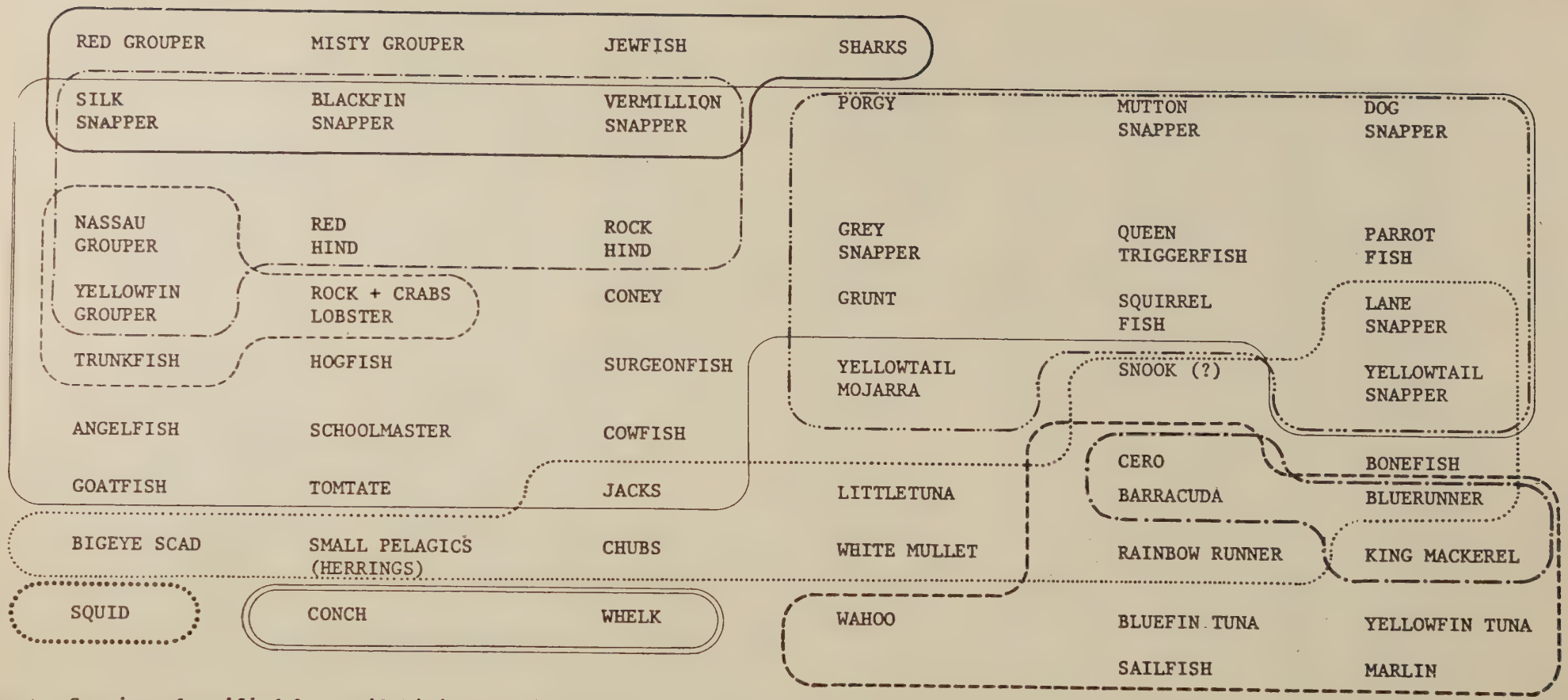

Fig.4 Species classified by availability to fishing gear (from Juhl 1975; Cole 1976) modified for BVI from information by Walters (pers. com. and others).

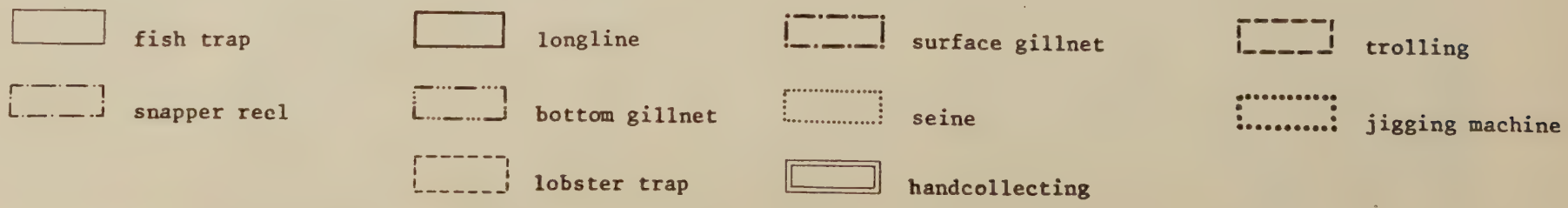

Figure 4 Species classified by availability to fishing gear (from Juhl, 1975; Cole, 1976) modified for BVI from information by Walters (pers. comm. and others)

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MANIPULATION OF FIXED GEAR AND THE EFFECT ON CATCH-PER-UNIT EFFORT

by

Bernard Einar Skud
National Marine Fisheries Service
Narragansett, Rhode Island, USA

INTRODUCTION

Historic reports of North American fisheries in the late 1800s often included records on the catch-per-vessel or per-trip (e.g. Goode, 1887) but I have not located any reference in this period that specifically used catch-per-unit effort (CPUE) as an indicator of stock abundance. In European literature, the earliest mention I located of this specific use was in an actual experiment by the Scottish Fishery Board (Garstang, 1900). The average "catch-per-haul per-trawl" in two areas was compared for a ten-year period, 1886-1896. Not all scientists accepted the results of this experiment and, judging from the remarks of Petersen (1903) and Hoek (1905) about other studies, the use of CPUE as a measure of abundance was not widely accepted at the turn of the century. Hoek argued that CPUE was an unreliable index, whereas he said that "... the total catch may be used with certainty for answering of the question whether over-fishing is taking place ..." Thereafter, although negative views continued (Heincke, 1913), there appears to have been a broader acceptance of the use of CPUE. Helland-Hansen (1909) presented a mathematical model for weighting CPUE by sub-areas; Thompson (1909) compared the "catch-per-CWT per 100 hours" of trawls in Iceland and the Faroe Islands; Russel (1915) used the "catch-per-day per 500 yards of net by sailing-drifters" in the North Sea to compare the fluctuations in the abundance of pelagic species; and Thompson (1916) used the "catch-per-skate" to document the changes in the abundance of Pacific halibut (Hippoglossus stenolepis). By the 1930s, references in the literature to CPUE were more frequent and included gear such as gillnets (Rounsefell, 1930; Hile and Duden, 1933; Van Oosten, 1935). A number of these papers discussed the criteria for selecting a unit of effort or compared different types of effort measurements (Thompson, et al., 1931; Graham, 1934; Thompson and Bell, 1934), and others used CPUE to study the survival and strength of year classes (Graham, 1938; Jensen, 1939). Ricker's (1940) paper may represent the culmination of this early examination but, even at this late date, the mention of "catch-per-unit-effort" in his title was enclosed by quotation marks - suggesting that the term was still not a common usage in the literature. Ricker presented a comprehensive mathematical model of CPUE and his work seems to have introduced a new era of study and use of the statistic that is continuing today.

In those early studies which included an examination of factors that affect CPUE, emphasis was on aspects concerned with population density, climatic conditions, fish behaviour, seasonal distribution and other factors that were unrelated to the manipulation of the gear, i.e. its handling or modifications (Garstang, 1900; Helland-Hansen, 1909; Hart, 1934). Of the few studies concerned on fisheries using fixed (stationary) gear such as longlines and gillnets. 1/ Perhaps the most detailed studies on the effects of modifications to stationary gear on CPUE were those in the longline fishery for Pacific halibut (Thompson, et al., 1931; Thompson and Bell, 1934). The changes examined were length of groundline (skate), hook-spacing, hook size and length of set (soak time). Hile and Duden (1933) and Van Oosten (1935) were among the first to examine the effects of handling (specifically, duration of set) on CPUE in fisheries using gillnets. They distinguished between measures of "fishing effort" and "fishing intensity", the former excluding and the latter including the dimension of time. Kennedy (1951) also emphasized the importance of duration of set of gillnets and Ricker (1958), summarizing the findings of these studies, concluded that the catch-per-unit-time, for many kinds of gear, tends to decrease from the time they are set to the time they are retrieved.

1/ My classification of fishing gear is similar to that of Alekseev (1971) and Rounsefell (1975). Fixed or stationary gear includes all devices by which capture is dependent on the organisms moving to the gear, in contrast to mobile gear by which capture is dependent on the movement of the gear.

Despite these early beginnings, the relative simplicity of stationary gear, especially longlines and traps, engendered the concept that the measure of fishing effort was straightforward and uncomplicated in comparison with mobile gear such as trawls and purse seines (Allen, 1963; Gulland, 1969; Rothschild and Suda, 1977). Because of this attitude, the effects of changes in the usage or of subtle modifications to stationary gear on the determination of CPUE were not fully appreciated and, until recently, few attempts were made to relate these changes to the economic aspects of fishing. The purposes of this paper are to review two examples of these changes - (1) hook-spacing in the longline fishery for halibut, and (2) duration of set in a pot fishery for lobster (Homarus americanus) - with respect to their impact on CPUE as a measure of abundance and to the potential economic advantage for fishermen.

LONGLINE GEAR : EFFECTS OF HOOK-SPACING

Between 1950 and 1970, most of the gear studies of demersal longline fisheries concerned the relation of hook size or shape to size selectivity (McCracken, 1963; Parrish, 1963; Saetersdal, 1963; Aasen, 1965; Hamre, 1968). In contrast, gear studies of pelagic longline fisheries emphasized the calculation of CPUE and these studies were the first to present data that cast doubts upon the interpretation of CPUE in longline fisheries.

Initially, in the Pacific halibut fishery, the length of groundline (skate of gear) was adopted as the standard unit of effort (Thompson, 1916; Thompson et al., 1931; Thompson and Bell, 1934). This measure was adopted after extensive study in which the authors concluded that no adjustment was necessary either for the number of hooks per skate or for the hook-spacing. Later, Bell (unpublished, circa 1940) concluded that effort was redefined accordingly. Japanese scientists had reached the same conclusion in the tuna fishery during the 1930s (Nakamura, 1952). Earlier still, Clemens (1920) used the hook as the measure of effort in studies of ocean pout (Macrozoarces americanus).

With qualifications and refinements, this relation of number of hooks to effort was accepted in theoretical studies of hook and line gear. Gulland (1955) and Beverton and Holt (1957) assumed that fishing power of longline gear was proportional to the number of unoccupied hooks and presented catch equations to correct for gear saturation. Ricker (1958) emphasized that the efficiency of the gear was reduced not only by those hooks that caught fish but by the loss of bait. Murphy (1960) extended the treatment of saturation and incorporated factors in the catch equation for the loss of bait and loss of hooked fish. Ionas (1966), Fridman (1973) and Gulland (1969) concluded that longline effort was increased simply by adding hooks and that the amount of effort could be expressed as the number of hooks multiplied by fishing time.

Because the theoretical definitions did not include explicit reference to hook-spacing or length of groundline, it is not possible to judge how the authors conceived the relationship of these factors to fishing effort (Skud, 1978). If the authors assumed a constant length of groundline (the practice in most longline fisheries), the definitions imply that catch-per-hook is independent of hook-spacing, because an increase in the number of hooks reduces the spacing between them. If hook-spacing was considered constant, then the length of goundline would increase as hooks were added but, once a hook was occupied or lost its bait, the effective spacing between baited hooks would change.

In the longline fishery for tuna, many of the references to the effects of hook-spacing were indirect as the authors were concerned with the number of hooks-per-basket and, usually, their interest was directed towards improving the efficiency of the gear. Shomura and Murphy (1955) reported the results of a hook-spacing experiment in which the catch (number of tuna) was 0.262 per basket for 6-hook gear (wide spacing) and 0.316 for 11-hook gear (narrow spacing). They concluded that there was an advantage to adding hooks, although the trend in the fishery had been towards reducing the number of hooks per basket. Murphy (1960) cited these results in reference to his modification of Gulland's (1955) catch equation. Murphy concluded that most of the increase on the 11-hook gear was the result of reducing localized saturation. He did not calculate the catch-per-hook and stated that, if school size was constant, CPUE would not be distorted. Skud (1978) re-examined Shomura and Murphy's (1955) data and calculated the catch-per-100 hooks: 2.9 for the 11-hook gear and 4.4 for the 6-hook gear, showing an increase in the catch-per-hook with hook-spacing.

Maéda (1967) discussed the "thinning of hooks" and concluded that there were advantages in reducing the number of hooks-per-length of mainline. Hirayama (1969) also was interested in improving the gear but specifically examined the "hook rate" with intervals of spacing between 100 and 200 ft. He noted the tendency for wider-spaced gear to catch more tuna per 100 hooks. But neither these authors nor others described the quantitative relation between spacing and CPUE or mentioned the need for adjusting the data for differences in hook-spacing (Otsu and Sumida, 1968; Wise and Fox, 1969; Rothschild and Yong, 1970; Shingu et al., 1974; Pella and Psaropulos, 1975; Rothschild and Suda, 1977). Kurogane (1968) examined hook-spacing in a Japanese longline fishery for demersal species and noted that narrow spacings were superior for catching blackcod (Anaplopoma fimbria) and that wide spacings were superior for halibut, but he did not relate his findings to a measure of abundance.

Thompson, et al. (1931) had considered hook-spacing in their review of measures of effort in the halibut fishery and had concluded that no correction was necessary. Skud (1972) reported on experimental fishing with four different spacings that showed that catch-per-hook increased with spacing, i.e. that effort was not proportional to the number of hooks as assumed in the existing "standard" measure of effort. Skud showed that this old standard had under-estimated the effective effort of wider-spaced gear by over 30 percent and, as a result, that stock abundance had been over-estimated. Subsequent experiments confirmed these findings and showed that catch-per-hook increased, but at a progressively decreasing rate, with hook-spacing (Hamley and Skud, 1978). The agreement with the experimental results and the unit of effort for the halibut fishery was re-defined accordingly. The new standard was described as an asymptotic function. Skud (1975) had re-examined the early data used by Thompson et al. (1931) and showed that these early estimates of CPUE also should have been corrected for differences in hook-spacing.

The interest in hook-spacing in other demersal longline fisheries has also been relatively recent. Several of these papers have been presented as unpublished documents at the Annual Meeting of the International Council for the Exploration of the Sea (ICES). These include reports from Working Groups of the Gear and Behaviour Committee that provide instructions for collecting and analysing pertinent data. For example, Karlsen (1977) examined factors such as gangion length, bait size and hook type as well as hook-spacing in a Norwegian longline fishery. In one of his experiments, he compared CPUE with increases in hook-spacing of 35, 50 and 100 percent. The corresponding catch-per-line decreased 16.8, 18.6 and 29 percent; whereas the catch-per-hook increased 11, 22 and 42 percent. These results too indicate that effort is not proportional to the number of hooks. Karlsen also experimented with hook-spacing increases of 200 and 300 percent and concluded that, at low catch rates, the gain in CPUE with hook-spacing is greater than at high catch rates. These and other studies in Norway were recently reviewed by Bjordal (1981).

The findings on hook-spacing have economic implications of importance to fishermen. As mentioned, the initial studies on hook-spacing in the longline fishery for tuna were designed specifically for improving the efficiency of the gear (Shomura and Murphy, 1955; Maéda, 1967; Hirayama, 1969). These studies showed that wider-spaced hooks caught more tuna per 100 hooks than narrow-spaced gear. Apparently the fishermen had been aware of this advantage, because Shomura and Murphy (1955) reported that the trend in the fishery had been towards reducing the number of hooks-per-basket. Skud (1972) also considered the economic advantages of wider hook-spacing in the halibut fishery. He pointed out that, in addition to the higher catch-per-hook, the wider gear required fewer hooks and less bait and that the baiting and hauling of the gear was faster. These advantages must be weighed against costs of additional groundline, soak-time, bait costs and other factors to determine the optimum operation for a particular vessel (Skud, 1972; Hamley and Skud, 1978). That the halibut fishermen appreciated these advantages is evident in the trend toward wider-spaced hooks which began as early as 1950 (Skud, 1972). The importance of other changes in the rigging of longline gear, as well as hook-spacing, to attain an optimum fishing operation was discussed by Bjordal (1981).

POTS AND TRAPS: DURATION OF SET

Fishing time is an integral component of catch-per-unit of effort (CPUE), yet consideration of soak time (duration of set or immersion) for pot gear (traps) has a relatively recent history in crustacean fisheries. For the most part, biologists have relied on the catch-per-haul to compute CPUE. Aside from differences in seasonal availability and gear design, this measure was accepted as a

reasonable estimate of relative abundance because pots in most fisheries were set and hauled daily. In other fisheries, however, soak time was only a few hours or, at the opposite extreme, many days. The longer soaks were not always intentional, being more often governed by weather conditions or vessel breakdowns. As fishermen added more gear or as new grounds were developed, soaks of several days were scheduled and became commonplace in certain fisheries, and biologists began questioning the reliability of catch-per-haul as a measure of abundance.

Simpson (1975) reviewed the literature on effort measurement in European trap fisheries (lobsters and crabs). He found general agreement among biologists as to the appropriate units of effort but said that little attention had been paid to the collection of such data. In particular he cited the lack of information on the differences in catch-per-pot relative to the number of days soaked.

Early studies of soak time were understandably limited in scope and covered only a few days, or even hours, of "set-over" gear (Thomas, 1951; Dow, 1961; Mason, 1965). One exception was the study by Robinson and Dimitriou (1963) on the spiny lobster (Panulirus sp.) with soak times up to 30 days. More recently data on longer soak times have been analysed by several authors. Rothschild et al. (1970) analysed data on soak time in the Alaska king-crab fishery, Thomas (1973) presented information on soak time from the Maine lobster fishery and Bennet (1974) discussed the effects of immersion time for the crab and lobster fishery off Devon, England. These studies showed that catch per pot-haul up to four days generally increased, but not in proportion to soak time. Robinson and Dimitriou (1963) had similar results but the increase continued beyond ten days. Munro (1974) had records of catch-per-trap for soaks as long as two weeks and used observations of divers to develop a comprehensive model describing the rate of capture and escapement of reef fishes in the Caribbean. Skud (1979) presented data from the offshore lobster fishery in the Northwest Atlantic in which the duration of set (soak time) was as long as 10 days. His results were comparable to those of Munro (1974), showing that the catch-per-pot reached a maximum some time after four days and eventually declined. The catch-per-pot and the day of the maximum catch differed seasonally. Skud used regression analysis to estimate the catch per pot per day (C/P/D) and these data were used to evaluate the utility of CPUE data from pots and to determine the optimum schedule of pot retrieval for the fisherman. The results clearly showed that C/P/D decreases with each successive day of set, much the same as Bennett (1974), McLeese (1970), Thomas (1958) and others have shown for pot fisheries and as Hile and Duden (1933) showed for gillnet fisheries.

The factors that cause the reduction in C/P/D with successive days of soak have been discussed extensively in the literature and only a brief comment is needed here. Escape from pots could be the major factor and its importance has been noted by Bennett (1974), Munro (1974) and others. Bait deterioration or the density of lobsters in the trap could also affect the rate of ingress by discouraging new entrants. Although the progressive decline of C/P/D may best be explained by escapement, the importance of other factors should not be dismissed.

Authors generally agreed that catch per haul was not an adequate measure of CPUE if soak time was variable, but the utility of C/P/D by itself is also limited in its application. Munro's (1974) study was particularly relevant in this regard. He discussed the limitations of C/P/D as an index of abundance. His model demonstrated the relation between ingress and escape (proportional to density) and showed that, if these parameters were constant, the catch would be asymptotic. (Robinson and Dimitriou (1963) and Austin (1977) also presented an equation showing that the catch of spiny lobster was asymptotic.) Basically Munro used the Walford-fit for the Brody-von Bertalanffy curve:

$$C_{s+1} = C_{\infty}(1 - r) + rC_s$$

where, C_S = The cumulative catch after a soak of s days

C_{∞} = The theoretical asymptotic catch attained after an infinitely long soak

r = The daily probability of retention in the trap ($p + r = 1.0$), where p is the probability of escapement

If the rate of ingress declines with time but escape remains constant, the catch will eventually fall below the asymptote. As previously noted, these trends were apparent in the data from the offshore lobster fishery and also in other pot fisheries (High and Worlund, 1979). Bennett and Brown (1979) also used Munro's equation in their discussion on the effects of immersion time and the use of CPUE as an index of abundance. Papers by Wilder (1948) and Krouse and Thomas (1975) on the size of escape "vents" support Munro's (1974) thesis and stress the importance of escape relative to the size composition of the catch as well as the necessity for considering trap construction in the standardization of CPUE. Application of Munro's index must also consider seasonal and behavioural changes in catchability such as discussed by Morgan (1979).

Austin (1977) presented a model for determining the "profit-maximizing soak time" for the spiny-lobster fishery in Florida. He reported an optimum of 6-7 days, but qualified his results because they were based on only 25 observations and on crude estimates of cost. He concluded that, as the exploited stock declines, so would the profit-maximizing soak time. Skud (1979) also discussed the economic importance of the changes in C/P/D to fishermen in the offshore lobster fishery. The optimum schedule of pot retrieval would, of course, vary with the carrying capacity of the vessel and hauling capability. Obviously a fisherman could increase his catch by scheduling retrieval of pots for more than one day, but this benefit would have to be weighed against the cost of the additional pots and other factors. For example, if a vessel was capable of carrying 400 traps but could only haul 100 traps per day, 2 and 3-day soaks would offer a decided advantage in catch. Using catch rates for June-September, the catch for a 10-day trip would be 3,300 kg for 1-day soaks and 5,190 kg for 2-day soaks, a 57 percent increase. From a 2-day to a 3-day soak the increase would be 23 percent. For soaks longer than three days the advantage was less than 10 percent and the justification for this stragegy would have to be weighed against costs and the higher risks associated with weather conditions, particularly in the winter. Because seasonal changes of catch apparently are more pronounced in coastal areas different criteria would have to be considered, as they would for fisheries for other species being taken in pots.

SUMMARY

The results of these studies on the manipulation of stationary gear - specifically hook-spacing of longline gear and duration of set for pots - indicate the complexity of estimating CPUE for these fisheries. Subtle changes can have a profound influence on the utility of this statistic as an index of abundance. The studies also emphasize the need for a continual evaluation of changes in the gear or the method of fishing to provide reliable indices of abundance for a given fishery. The degree of refinement needed for estimates of CPUE should be evaluated in terms of management goals and the practicality of collecting the data necessary for the specified refinements.

The studies also show that adjustments to the gear or method of fishing can have economic advantages for the fisherman in determining the optimum operation in a particular fishery. Direct financial gain may be realized through manipulation of the gear that improves the catch rate or, indirectly, through reductions in the cost of fishing. In both the pelagic and demersal longline fisheries discussed in this report, the fishermen were aware of the advantages of wider hook-spacing much before its significance was appreciated by biologists. In pot fisheries, there generally is little evidence to show that fishermen are retrieving their gear at the optimum rate, suggesting either that the potential advantages are not realized or that weather conditions, market demand or other factors dictate the methods of operation.

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MESH SIZE REGULATION AND ITS ROLE IN FISHERIES MANAGMENT

by

R. Jones
Marine Laboratory
Aberdeen, Scotland

Abstract

This paper is concerned with the principles of mesh regulation, its role in fisheries management and difficulties encountered in its implementation.

The theoretical basis of mesh regulation is based on the concept of an "optimum harvesting strategy", i.e. the fact that, for many commercially important fish species, recruitment is unrelated to spawning stock size over a wide range of stock sizes. This makes it possible to conceive of an optimum exploitation pattern for exploiting each year class throughout its life, irrespective of its absolute magnitude. Within this context, theoretical considerations are concerned with the probable age at which a fish is likely to be captured. If, for example, fish are caught when they are very young, the catch will typically consist of large numbers of very small individuals. This will provide a numerically very large catch but not necessarily a large weight of fish. Conversely, if fish are not caught until they are very old, the catch will tend to consist of a relatively small number of relatively large fish. Again the aggregate weight of catch may not necessarily be large. The theoretical approach is to determine the best average age or size at which to capture so as to maximise the sustainable yield in weight per year class entering the fishery.

There are various ways of achieving this, and one of these is by regulating the age (or size) of first capture directly. This may be done by regulating the mesh size, in a demersal drag-net fishery, or the hook size as in a hook and line fishery. One object of mesh regulations therefore is to influence the sustainable yield in the long-term. Other objectives are to protect juvenile fish from capture, and to try to ensure that sufficient fish survive to maturity. This may be especially important for stocks which are exploited at so high a level that there is a danger of recruitment failure due to diminished stock size.

There are a number of difficulties with mesh regulations, one of which is that it is not usually possible to demonstrate that an actual change in mesh size has had the expected effect on catches. This is because natural fluctuations in stock size (and catch) tend to be much larger than the expected effects of the changes in mesh size that have been implemented in practice. This does not necessarily mean that mesh regulations have no effect. It does mean, however, that the effects of mesh regulations cannot be demonstrated, in practice. Because of this, and because the short-term effect of a mesh increase is likely to be a reduction in catch, it may be difficult to convince industry that such restrictive measures are really necessary. Other difficulties include:

(a) How to persuade industry to accept regulatory measures if different sectors of the industry are likely to be affected to different extents (for example, fisheries for fish meal frequently require smaller-meshed nets than fisheries for fish for human consumption

(b) How to determine the best mesh size for a multispecies fishery such as a demersal trawl fishery

(c) How to ensure enforcement in situations where it may be possible to corrupt the enforcement officers

(d) How to prevent evasion of regulations as might be done, for example, by fitting one codend inside another as to reduce the effective mesh size when in use

(e) How to compromise between the spirit and the letter of the law; for example, to comply with the intention of a regulation, it may be appropriate to require the average mesh size to be of a certain size, but for legal purposes it may be necessary to require that no meshes are below a certain size.

In conclusion, it must be accepted that there are a number of difficulties associated with mesh regulations, but equally, it should be pointed out that none of them need be insuperable.

1. INTRODUCTION AND GENERAL MANAGEMENT CONSIDERATIONS

The general history of fisheries throughout the world shows that there has been a gradual increase in exploitation, partly due to an increase in the rate of exploitation stocks close to the land and partly due to an expansion of fishing effort to more distant fishing grounds. Associated with this increase in effort, there has been a decline in the catch rates on certain grounds and in many cases an increase in the quantities of small fish, including the juveniles of economically important species taken in coastal fisheries. Because of this, as well as the growing recognition that stocks may not be inexhaustible, it is generally recognised that stocks should be managed, even if only to prevent further declines.

There are a number of possible management objectives, not all of which are necessarily compatible one with another. For example, one important objective is to exploit a stock so as to obtain an "optimum" return or yield from the fishery. Another is simply to ensure that it is never exploited so heavily that its continued existence is threatened. In some parts of the world the principle objectives are socio-economic: for example, to provide employment to fishermen.

If the objective is to optimise something, there may be different things that one may wish to optimize, or maximize. For example, one may wish to maximise the total yield that can be removed annually from the stock. This may be a desirable national objective. An alternative is to maximize the total profit from the industry. This is likely to be an objective if a fishery were exploited by a single owner.

In practice, there are usually many owners (often individual fisherman) who operate more or less in competition with one another. From the viewpoint of any one fisherman, a suitable objective therefore would be to maximize the catch rate per boat. In practice, however, so long as it is profitable to do so, the tendency is for more and more boats to be built until the catch per boat drops to a level at which it is no longer profitable to build more boats. Theoretical considerations and experience show that under these conditions the total fishing effort is likely to be considerably higher than it would be if the objective were to maximise either total yield or total profit.

Thus, so long as it is uncontrolled, fishing is likely to increase to the point where it is no longer profitable to build more boats. The danger then, is that the spawning stock will be reduced to the point where there is a possibility of a stock collapse. This may be particularly so for those stocks that are influenced by large natural fluctuations in stock size. Under favourable natural conditions, for example, a stock may be able to withstand a relatively high level of fishing, whereas, under other and less favourable natural conditions, the same level of fishing effort may be far too high and the stock may be driven to a dangerously low level.

Fish stocks may be managed by controlling fishing effort directly, by controlling catch, through quotas, by controlling the age and size at which the fish are first exploited, by restricting fishing either in certain areas, or at certain times of the year, or by measures designed to prevent habitat deterioration. Of these, it is regulation of the size at first capture that is discussed below, since it is this measure that is concerned with mesh size regulation.

Control of the size at first capture can be an important measure for regulating fisheries in which the amount of fishing is not otherwise controlled. By introducing an appropriate minimum size of mesh, for example, it is possible to protect juveniles so as to give them time to grow to an economically useful size before they are harvested. If necessary, individuals can also be protected from exploitation until they are large enough to spawn, and in this way the size of the spawning stock can be protected.

2. OBJECTIVES OF MESH SIZE REGULATION

There are basically two reasons for regulating mesh size. One is to conserve the spawning stock and the other is to increase the long-term sustainable yield.

2.1 Conservation of the spawning stock

In situations where fishing effort is unregulated, there is the possibility that effort may become so high that there is a danger of a stock collapse, due to a depleted spawning stock and a resultant recruitment failure. If this danger exists, and it is not practical to regulate fishing effort directly, an increase in mesh size may be a useful alternative means of conserving the spawning stock. A suitable choice of mesh size should reduce the rate of capture of juveniles, and make it more likely that an individual will survive to the size of first maturity and have an opportunity of spawning at least once.

2.2 Regulation of long-term yield

Regulation of long-term yield is based on the concept of an "optimum harvesting strategy". For many commercially important fish species, recruitment is unrelated to spawning stock size over a wide range of stock sizes. It is realistic therefore to conceive of an optimum exploitation pattern, or harvesting strategy, which leads to the optimum yield per year class. The basic theory is summarised below, and considered in greater detail in Section 4.

Regulation of the age (or size) of first capture, ensures that the full effects of exploitation are felt only by the older (or larger) individuals. Theory is based on the assumption that changes in the age (or size) of first capture will cause stock size to change from one equilibrium level to some other level. Theoretical computations are largely concerned with the effects of changing from one age (or size) of first capture to another. Changes may be immediate, long-term, or transitional.

The immediate effect of an increase in mesh size, is to lose some animals that would otherwise have been captured. The immediate effect therefore is a loss in catch and earnings for all the vessels that increase their mesh size.

Some of the fish that escape through the larger meshes will be captured eventually and by then they will have had time to grow older and larger. Other individuals will die of natural causes however, and not be caught at all. This means that, out of a given number of recruits, the long-term effect of an increase in mesh size will be a decrease in the number caught and an increase in the average size of individuals caught. Provided the gain in weight, due to the growth of the individuals that happen to be caught, is greater than the loss in weight due to those that are not caught at all, there should be a long-term benefit.

Even if the long-term effect of an increase in mesh size is beneficial, the immediate effect will involve a loss. There will therefore be a transition period before the full long-term benefit is experienced. The length of the transition period will depend on the length of time required for the youngest fish in the catch to pass completely through the fishery under the new conditions of mesh size. In general the transition period will depend approximately on the number of years for which an individual is subject to exploitation. In heavily exploited stocks, the bulk of the catch consists of fish that have been subject to exploitation for only a few years. In these stocks, therefore, possibly as much as 70-80 percent of the long-term benefit might be expected after a transition period of only two to three years. In the case of a lightly exploited stock, individuals will tend to be exploited for a longer period and the transition period will therefore be longer also.

In summary, a change of mesh size can usually be regarded as beneficial if it causes catches, in the long-term, to be greater than they otherwise would have been. A mesh regulation does not necessarily lead to an increase in the absolute level of catches, however, since these will continue to be influenced largely by natural variations in the level of recruitment.

3. PRACTICAL DIFFICULTIES AND MANAGEMENT PROBLEMS

In spite of its basic theoretical simplicity, the determination of the "optimum" mesh size can be associated with a number of practical difficulties and management problems.

3.1 Demonstrating the effect of a change in mesh size

Perhaps the greatest difficulty with a mesh regulation is that it is usually impossible to demonstrate that a change in mesh size has had the effect that is predicted by theory. This is a consequence of recruitment fluctuations of an irregular nature in the short-term and of periodic variations in recruitment in the long-term. As a result, there tend to be natural fluctuations in stock size that are considerably larger than the mesh-change effect one may be expecting.

All that can be said, in practice, is that the effect of a change in mesh size is to cause catches, in the long-term, to be a certain percentage higher or lower than they otherwise would have been. Because, in practice, natural variation is likely to be so much larger than an expected effect, the effect of a mesh regulation is usually statistically undetectable.

Ths does not necessarily mean that mesh regulations have no effect. It does mean, however, that the effects of mesh regulations usually cannot be demonstrated and this may make it difficult to convince industry that a regulation is likely to be beneficial (see next section).

3.2 Convincing industry of the need for restrictive measures

Conservation measures are almost invariably restrictive in the short-term. For example, there can be the need to restrict fishing effort, the need to increase mesh size or the need to interfere with activities that might cause habitat deterioration. An objection to an increase in mesh size, therefore, is that there is likely to be an immediate loss and that it could be several years before long-term benefits are likely to be experienced. Because of this, fishermen, and sometimes administrators, may need to be convinced of the need for such measures, and this may be difficult to achieve in practice because of the natural variability of recruitment. Even stocks which are believed to be a very low level can sometimes produce good year classes and lead to temporary increases in catches. This may make it difficult to convince fishermen that a stock is being over-exploited and that restrictive measures are really necessary.

Uncertainty can also arise because of periodic fluctuations in stock size of a fairly long period, i.e. perhaps 50 years or more). Thus, until sufficient data have been accumulated to quantify these cycles, management may find itself confronted with a declining stock but without any means of knowing for certain whether this is due to exploitation or to natural causes.

One way of minimizing these objections might be to increase the mesh size gradually or to increase the mesh size at a time when the stock happened to be increasing due to natural causes, such as when there is a strong recruit year class. However, whatever course of action may seem appropriate, little is likely to be achieved without the understanding, and acceptance of the necessity for it, on the part of industry.

3.3 Determining the best mesh size for a fishery

Determining the best mesh size for any one species can be a straightforward business. Determining the best mesh size for a fishery in which more than one species is caught by the same gear, however, is likely to be much less straightforward.

In the North Atlantic, where demersal fisheries are based on a relatively small number of species of value, this problem is not too difficult. In tropical demersal trawl fisheries, however, where there may be several hundred commercially valuable species, the mesh size has to be a compromise between the best mesh sizes for the individual species. Some species (e.g. Trichiurus) are long and thin, whereas others (e.g. Apogon) are short and fat. Others may be small-bodied when fully grown, so that the best compromise mesh size for a tropical fishery may be anything but the best mesh size for many of the species individually.

3.4 Meshing

A problem that can occur if a mesh size is too large is that of "meshing", i.e. the occurrence of fish that have become lodged in the meshes of a net while trying to escape. Meshing, if it occurs on a large scale, is a nuisance to fishermen because of the time needed to remove meshed fish individually from a net.

3.5 Socio-economic problems

An increase in mesh size is less likely to be accepted if benefits are not experienced by all sections of the industry. Thus, if an increase in mesh size favours one section of the industry at the possible expense of another, there is likely to be a conflict of interests. Possible sources of conflict involve inshore subsistence fishermen who may want to use relatively small mesh nets, and offshore fishermen who may be prepared to use larger nets with larger mesh sizes. Alternatively, there may be a conflict between fishermen who wish to use small meshes to catch large quantities of small-bodied fish for processing into fish meal, and fishermen who are prepared to use large meshes to catch larger fish for human consumption. So long as there are conflicting aims, enforcement is likely to be difficult to achieve in practice.

3.6 Quality of enforcement

To be effective, some way of enforcing a mesh regulation is essential, which means that the quality of enforcement must be reasonably high. If, for example, the enforcement officers happen to be people with very low salaries, who may be tempted by bribes to relax their vigilance, then enforcement is not likely to be effective.

3.7 Chafers and double codends

To be effective, a mesh regulation must ensure that the mesh size, when the net is fishing, is not less than some specified amount. There is, then, the danger that the mesh size when the net is fishing is less than the measured mesh size. This could arise if, for example, double codends (i.e. one codend inside another) were used. Similarly, if pieces of canvas or netting (known as chafers) are attached to a codend for strengthening purposes, the effective mesh size may be smaller than the apparent mesh size. Chafers are usually sub-divided into bottom chafers and top-side chafers, these terms referring to the part of the codend to which the chafer is attached.

Because of the possibility of using a double codend, it may not be sufficient to attempt to regulate the mesh size by prescribing a minimum mesh size for factory-made codends. This might appear to be a useful measure but, whether it is employed or not, it is likely to be necessary to take measures also to permit inspection of codends at sea. To take account of double codends and chafers, it may be necessary to word regulations to take account of the following points:

(a) That no device shall be used by means of which the mesh size is, in effect, diminished.

(b) That inspectors may be authorized to inspect nets at sea as well as ashore.

(c) That, if exceptions are to be permitted, the regulations should clearly specify what form these exceptions may be permitted to take; in the Northeast Atlantic, for example, consideration has been given to:

- A chafer of netting, having in all its parts a mesh twice the size of the mesh in the codend when measured wet, fastened along the fore and lateral edges only, and that is at least $1\frac{1}{2}$ times the breadth of the codend.
- A "multi-flap" chafer, i.e. a top-side chafer made up of numerous flaps, each fastened along the fore and lateral edges only.

If possible, the use of chafers and covers should be avoided and this may be possible if the codend is made of strong enough material.

3.8 Minimum landing sizes

In the North Atlantic, minimum landing sizes have been specified for the principal species in conjunction with existing mesh regulations. The object is to aid enforcement by discouraging fishermen from using very small-mesh nets and then having to reject a relatively high proportion of their catch. This can be done by making the minimum landing size related, in an appropriate way, to

the 50 percent length of the legal mesh size. To be effective, some under-sized fish will unavoidably be caught and have to be rejected. The loss, or waste, of these fish can then be regarded as the cost of adopting this particular enforcement measure.

If there is to be a minimum landing size, the regulations should specify that under-sized fish should not be sold, or landed, but should be returned to the sea.

In practice, minimum landing sizes may be really effective only in regions where there is relatively little market demand for small fish. In regions where small fish are in demand for duck food, for feeding pond fish or for fish meal, for example, the introduction of a minimum landing size may only lead to an illegal market in undersized fish.

Without minimum landing sizes, however, there may be an even greater economic incentive to fish with a mesh size smaller than that specified in a regulation.

3.9 Exemptions from mesh regulations

When a mesh size is to be increased, there may be pressure, if only for a transition period, to permit exemptions to mesh regulations for certain types of gear or for certain regions.

A problem with exemptions is that legal loopholes tend to be created and these may enable people to escape conviction.

3.10 Mesh differentials

Codends made of different materials can have different selective properties even if the mesh size is the same.

To allow for this, it may be necessary to:

(a) Frame a mesh size regulation with reference to a particular cod-end material.

(b) Specify "differentials" (i.e. conversion factors) so that the mesh size for one material can be converted to an equivalent in terms of the mesh size for some other material.

(c) Specify whether a net is to be measured wet or dry.

3.11 Standardization of mesh-measuring methods for enforcement purposes

A difficulty with all mesh measurements is the specification of the amount of tension to put on the netting when the measurements are made. When measuring a mesh size, for example, different individuals may stretch a piece of netting by different amounts. The tension can also be influenced by the number of meshes measured at any one time. Alternatively, when measuring individual meshes with a wedge-shaped gauge, there is the difficulty of deciding with what pressure to insert the gauge into the netting.

Because of this difficulty, it may be necessary to treat separately the problem of measuring the size of a particular mesh from the problem of deciding if the meshes of a particular codend are under-sized for legal purposes.

For measuring individual meshes with a standard tension between knots, two methods have been employed:

(a) For scientific purposes in the North Atlantic, a special gauge has been constructed so that the internal stretched mesh of a single mesh can be measured with a predetermined amount of tension between the knots.

(b) An alternative method is to construct a wedge-shaped gauge with a specified taper and to standardize the tension by hanging a specified weight on it after it has been inserted through a mesh.

For legal purposes, because of the statistical variation in mesh sizes under natural conditions and because of the difficulty of standardizing methods of measurement, it may not be enough to measure a number of meshes to decide whether or not a particular cod-end contravenes a regulation.

In the Northeast Atlantic, to avoid legal loopholes, it has been found appropriate to state that:

(a) No meshes shall be smaller than the minimum size.

(b) The minimum size shall be such that when the mesh is stretched diagonally lengthwise of the net, a flat gauge 2 mm thick of the appropriate width shall pass through it easily when wet.

The appropriate width of gauge in relation to any type of net in any type of the convention area is then stated in each case.

An implication of the wording is that the average mesh size in use will have to be larger than the minimum mesh size specified in the regulation, and this should be taken into account when determining the minimum mesh size.

4. THE THEORETICAL BASIS OF MESH SIZE REGULATION

Experience has shown that, when a stock is moderately exploited, it does not necessarily dwindle away and collapse after a few years. Instead, the effect of exploitation is more likely simply to be an initial decline in the stock, associated with a decline in the catch rate. Provided there is no further increase in effort, the stock then is likely to stabilize itself at a level lower than it otherwise would have done before but not to decline indefinitely. In general, experience suggests that stocks are able to maintain themselves under even moderately high rates of exploitation.

A simple model is depicted in Figure 1. This shows the factors affecting the numbers in a stock. Each year the number in the stock is augmented by an influx of young fish commonly known as "recruits". At the same time, there is a steady rate of removal of fish, partly due to fishing and partly due to natural causes. If a stock maintains itself under these conditions, it may be supposed that in the long term the following equilibrium equation ought to hold:

Recruits = natural losses + number caught

Figure 2 shows the same considerations applied to the weight of fish in the stock. Here the weight of individuals is augmented partly by the weight of recruits produced each year and partly by the growth of the individuals in the population. At the same time, there will be a loss in weight comprising the weight of fish removed. In the long-term, provided the stock does not collapse, the following equilibrium equation ought to hold:

Recruits + growth = natural losses (in weight units) + yield in weight

Re-arrangement of these terms gives an equation for expressing the annual catch in weight from a stock in equilibrium. This is:

Yield in weight = weight of recruits + growth - natural losses (in weight units)

This simple analysis shows that yield is partly dependent on recruitment and partly on the difference between growth and natural mortality in the exploited part of the stock.

4.1 The concept of an optimum harvesting strategy

The determination of the effect on yield of, for example, a change in size is usually done on the basis of principles described by Beverton and Holt (1957). These authors noted that, for very many commercially-exploited fish species, recruitment is highly variable and apparently unrelated to the size of the spawning stock, at least over a relatively wide range of stock size. For this reason, the contribution of recruitment to yield can be treated separately from the contribution due to growth and natural mortality. This approach leads to the concept of an optimum harvesting or yield-per-recruit

strategy, that is providing a stock is not reduced to a level at which recruitment failure might occur, the problem reduces to that of determining the optimum combination of mesh size and fishing effort for harvesting each year class, whatever its absolute numerical strength.

4.2 Sub-division of the stock into age groups

To further understand the principles on which this approach is based, it is not sufficient to sub-divide the stock into two parts (spawning and non-spawning) as in Figure 3. Instead, it is necessary to appreciate that a stock is made up of a number of age groups in different proportions.

Figure 4A shows the sub-division of a stock into age groups at the beginning of a year. It is supposed that there is a certain number of one-year old fish, a certain number of two-year olds, so many three-year olds, and so on. As the year progresses, the numbers of fish in each group gradually decline as a result of a loss of fish partly due to fishing and partly due to natural causes. The situation by the middle of the year, for example, might be shown in Figure 4B. By the end of the year (Figure 4C), corresponding to the beginning of the following year, all the individuals in age group 1 will have declined in numbers and become transformed into age group 2. Similarly the 2's will have become 3's and the 3's will have become 4's, and so on. At the same time, eggs will have been produced and a new year class formed to provide a fresh lot of recruits. Under theoretically ideal conditions of stability (i.e. constant recruitment and mortality from age group to age group), the situation at the beginning of one year should be the same as that at the beginning of the preceding year. The stock will have successfully reproduced itself and may be said to be in a state of dynamic equilibrium. It may be thought of as being dynamic in the sense that the numbers in each age group are continuously declining and changing from one age group to the next. At the same time, it can be regarded as being in equilibrium provided that the overall age composition reproduces itself from year to year. In this situation, the age composition is referred to as "a stable age composition".

4.3 The biological "model"

If the concepts depicted in Figures 3 and 4 are combined, the result is a biological "model" that can be used for inferring the effect of changes in fishing effort, or age of first capture, on a stock.

The first step is shown in Figure 5. It depicts the numbers in each group in the stock. It represents either:

(a) The decline in numbers in a single year class throughout the course of its life,

or, (b) The stable age distribution in the stock at any moment, on the assumption that the stock is in a state of dynamic equilibrium as described above and in Figure 4

Figure 6 introduces the concept of deaths. While, for example, the one-year olds decline until they become two-year olds, fish are dying and being removed. The number of deaths will then be equivalent to the hatched part of the histogram in the figure. The catch from each age group will therefore be generated as a percentage of the total deaths in each age group as shown in Figure 7.

At a certain age, the fish will be large enough to mature and produce eggs. Figure 8 shows that part of the stock is mature and able to produce eggs. These eggs will hatch into larvae and the survivors will eventually become recruits, as shown by the dotted line.

Figure 8 also shows the extension of the simple concepts in Figures 1 to 3, to take account of the fact that a stock is made up of a number of age groups (or year classes). To allow for weight as well as numbers, it is necessary to take account of the fact that, as fish age, they increse in weight due to growth. A given number of old fish will be heavier than the same number of young fish and this factor has to be taken into account when computations are done.

4.4 The effect of exploitation on the size of the spawning stock

Figure 9 shows the effect of different levels of exploitation on the proportion of the stock that may attain maturity. Thus, Figure 9A shows the situation in which the rate of exploitation is relatively very low. As a result, the rate of decline from one age group to the next is relatively small, so that a relatively large proportion of the total stock consists of fish of mature age.

By comparison, Figure 9B shows the situation where the rate of exploitation is relatively high. Here, even if the annual recruitment is assumed to remain unchanged, the rate of decline from one year to the next will be very much higher, so that the proportion of the total stock able to reach maturity will be very much lower than before.

Figure 9 shows how the egg production from a given number of recruits can be expected to decline as the rate of exploitation increases.

It is believed that, in the virgin, unexploited stock, total egg production is greatly in excess of that required to produce the number of recruits that normally survive. As a result, it is generally accepted that, up to a point, exploitation - although causing a decline in the number of spawners - need not necessarily lead to a decline in the annual recruitment to the stock. It is only when the rate of exploitation reaches some critical level that the spawning stock becomes so low that recruitment begins to decline and the stock starts to collapse. Good management aims to prevent the level of exploitation from ever reaching this point.

4.5 The effect on the spawning stock of the age of first capture

The proportion of spawners in the stock is influenced not only by the rate of exploitation but also by the age at which the fish are first subject to exploitation. Figure 10A, for example, shows a typical situation in a stock subjected to a high rate of exploitation from a relatively early age. Numbers decline rapidly from age group to age group and the percentage of spawners in the stock is relatively very low.

Figure 10B shows the situation for the same stock after an increase in mesh size so that the age at first capture is postponed. Up to the new age of first capture, the decline in numbers is relatively slow because it is due to natural causes only. It is only after the age of first exploitation that the decline is as rapid as it was before. Comparison of Figures 10A and 10B shows that, with a higher age of first exploitation, the proportion of spawners for a given number of recruits should be higher than before.

4.6 Mesh regulation as a means of conserving the spawning stock

One of the objectives of good management is to ensure that a spawning stock does not become so small that there is danger of a recruitment failure. Figure 9 shows that one way of doing this is by limiting the amount of exploitation. Figure 10 shows that alternatively it may be done by adjusting the age of first capture. In the case of a demersal trawl fishery, for example, this can be done by regulating the mesh size at an appropriate value.

4.7 Mesh regulation as a means of increasing the yield per recruit

The problem remains of determining the effect on the catch of an increase in mesh size. In this connection, it is important to separate immediate, transitional and long-term effects.

The immediate effect of an increase in mesh size is to lose some fish that would otherwise have been captured. The immediate effect, therefore, is a loss in catch and earnings for all vessels that increase their mesh size.

Some of the fish that escape through the larger meshes will be captured eventually after they have had time to grow older and larger. Not all will be caught in this way, however, since some will die from natural causes. Therefore, out of a given number of recruits, the long-term effect of an increase in mesh size will be a decrease in the number caught. Nevertheless, because those fish that are caught will be larger, there is the possibility that the gain in weight due to growth will be greater than the loss in number due to natural causes. Provided this is so, the increase in mesh size will have resulted in an increased yield in weight in the long term.

Even if the long-term effect of an increase in mesh size is beneficial, the immediate effect will involve a loss. There will therefore be a transition period before the full long-term benefit is experienced. The length of the transition period will depend on the length of time required for the

youngest fish in the catch to pass completely through the fishery under the new conditions of mesh size. In general the transition period will depend approximately on the number of years for which an individual is subject to exploitation. In heavily-exploited stocks, the bulk of the catch consists of fish that have been subject to exploitation for only a few years. In these stocks, therefore, much of the long-term benefit, possibly as much as 70-80 percent, might be expected after a transition period of only two to three years. In the case of a lightly-exploited stock, individuals will tend to be exploited for a longer period, and the transition period will therefore be longer also.

The situation is depicted in further detail in Figure 11. This shows histograms of numbers in the sea exactly as shown in Figure 10. In addition, the numbers caught have been included, both as part of each histogram and also repeated separately to the right of each diagram.

Figure 11A shows the catch composition expected from a fishery subject to a relatively high rate of exploitation and a low age of first capture. The catch consists primarily of young fish.

Figure 11B shows the same fishery but with the age of first capture increased. Comparison with Figure 11A shows that some of the very smallest fish would no longer appear in the catch but that more old (and hence more large) fish should be captured.

There are two important differences between the catch compositions shown in Figure 11. The first is that, with the larger mesh, the average size of the fish in the catch would be greater. The second is that, with the larger mesh, fewer fish would be caught. It follows that, as the mesh size is increased, the number caught declines and the average weight increases. Calculations show that it should be advantageous to increase the mesh size, provided that the weight gains due to the growth of the fish are sufficient to offset the numerical losses due to natural causes. Theoretical considerations show that, for any given species subject to any given rate of exploitation, there should be an optimum mesh size at which the potential yield per recruit is at a maximum.

4.8 Relating age or size of first capture to mesh size

Once an optimum age of first capture has been determined, it is necessary to determine the corresponding mesh size. For any one species and fishing gear, this is not particularly difficult and can be determined experimentally and in several stages.

The first step is to convert age of first capture to length at first capture. If the species can be aged, this can be done directly from an age/length curve for the species concerned. If it cannot be aged, the optimum length of first capture should be determined by using one of the methods of handling length composition data directly (Gulland, 1961; Jones, 1981).

A second step necessitates experiments to determine a selection curve or "ogive". This is simply a curve-relating length of fish to proportion retained, for a given net or gear. From such a curve it is possible to determine the 50 percent length, i.e. the length of fish at which 50 percent are retained and 50 percent released.

Finally, by preparing a number of selection curves, for different mesh sizes, it is possible to arrive at a relationship between mesh size and 50 percent length. It is this relationship that is used for relating mesh size to fish length.

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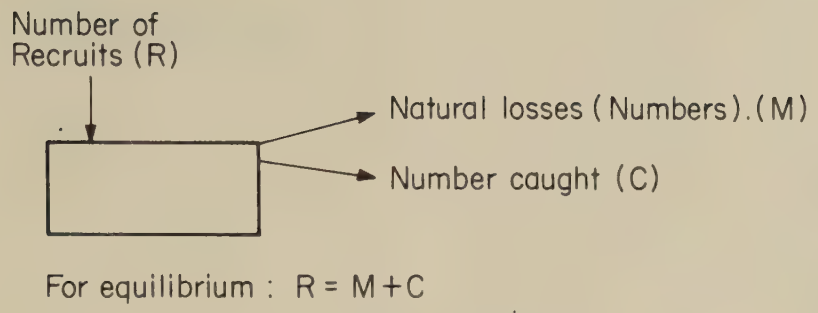
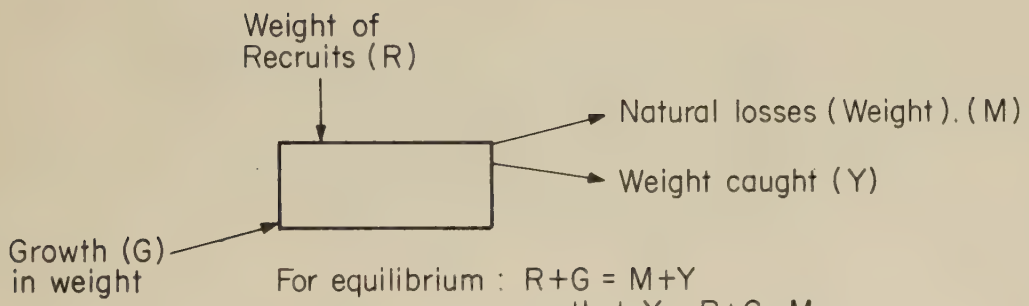


For equilibrium : $R = M + C$

Fig. 1 The exploited stock (Numbers)



For equilibrium : $R + G = M + Y$
so that $Y = R + G - M$

Fig. 2 The exploited stock (Weight)

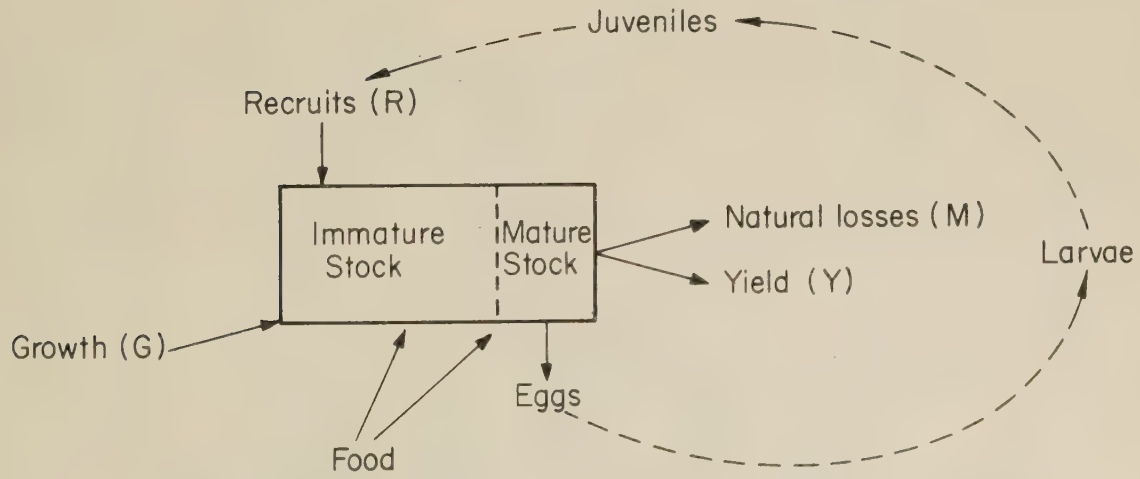


Fig. 3 A simple dynamic model

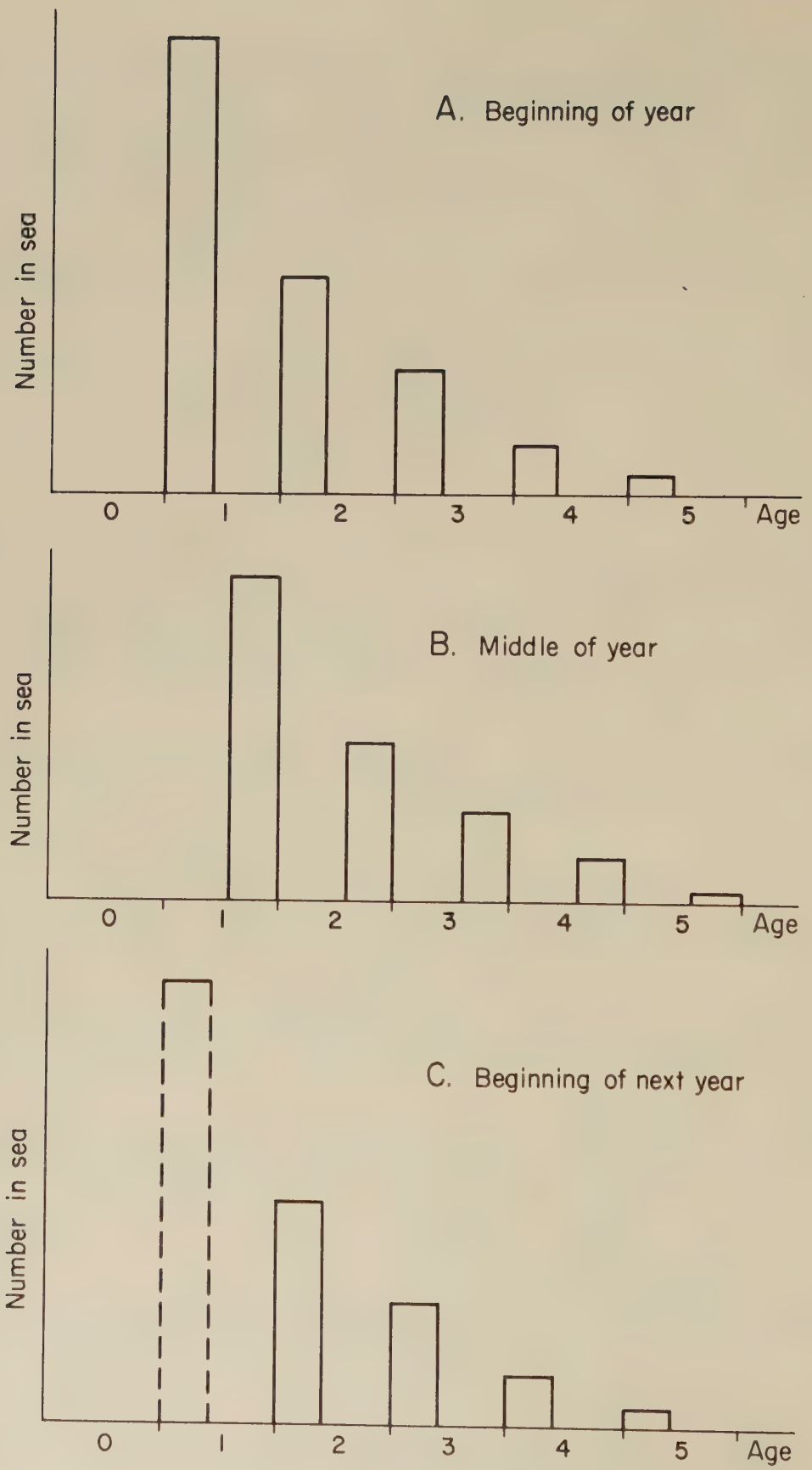


Fig. 4 Changes in age composition during a year

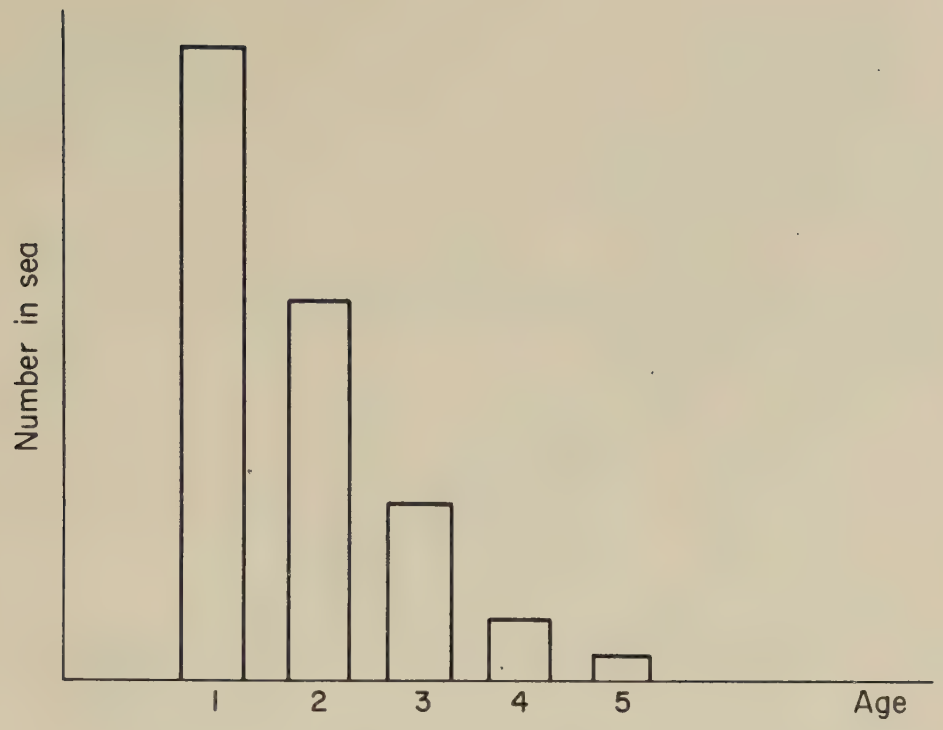


Fig. 5 The decline in the numbers in a single year class during the course of its life

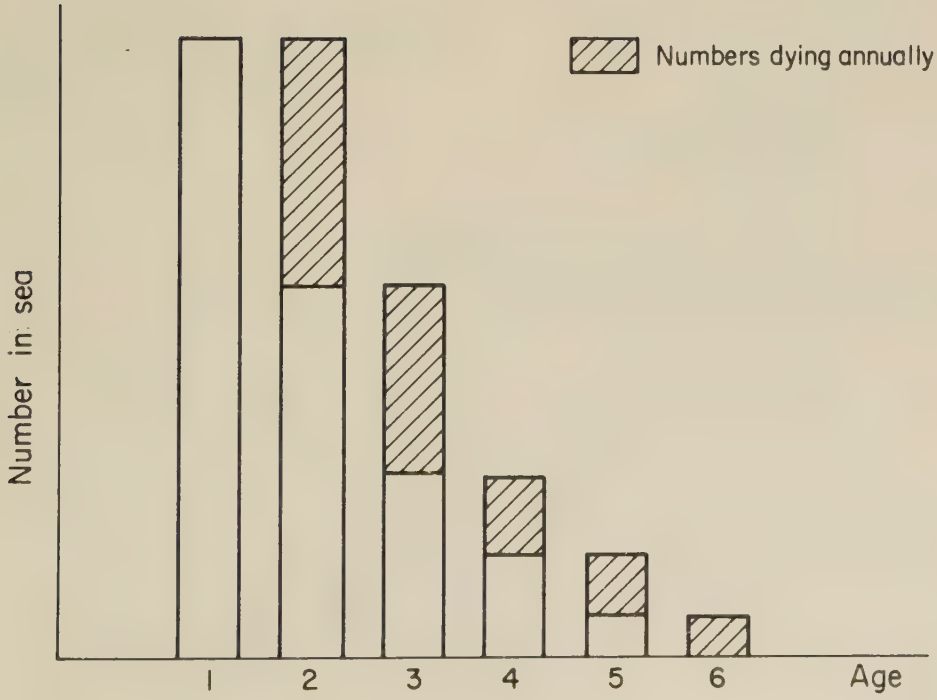


Fig. 6 Showing the relationship between the numbers in the sea and the numbers dying

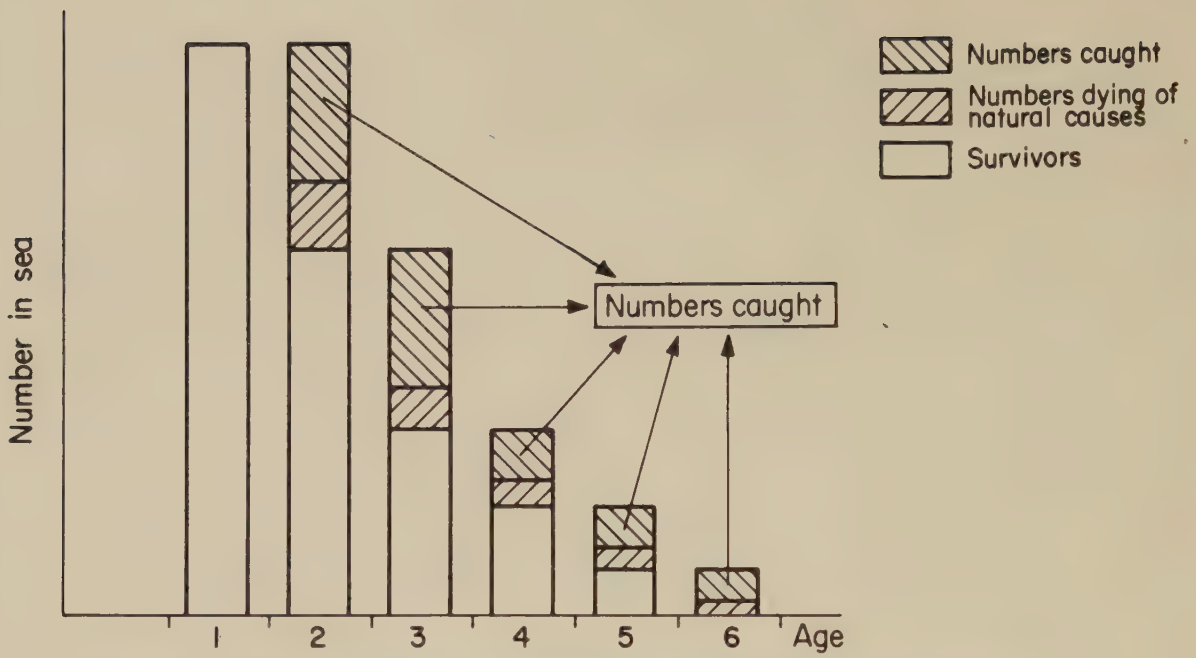


Fig. 7 Showing the relationship between the numbers in the sea, the numbers caught, and those dying of natural causes

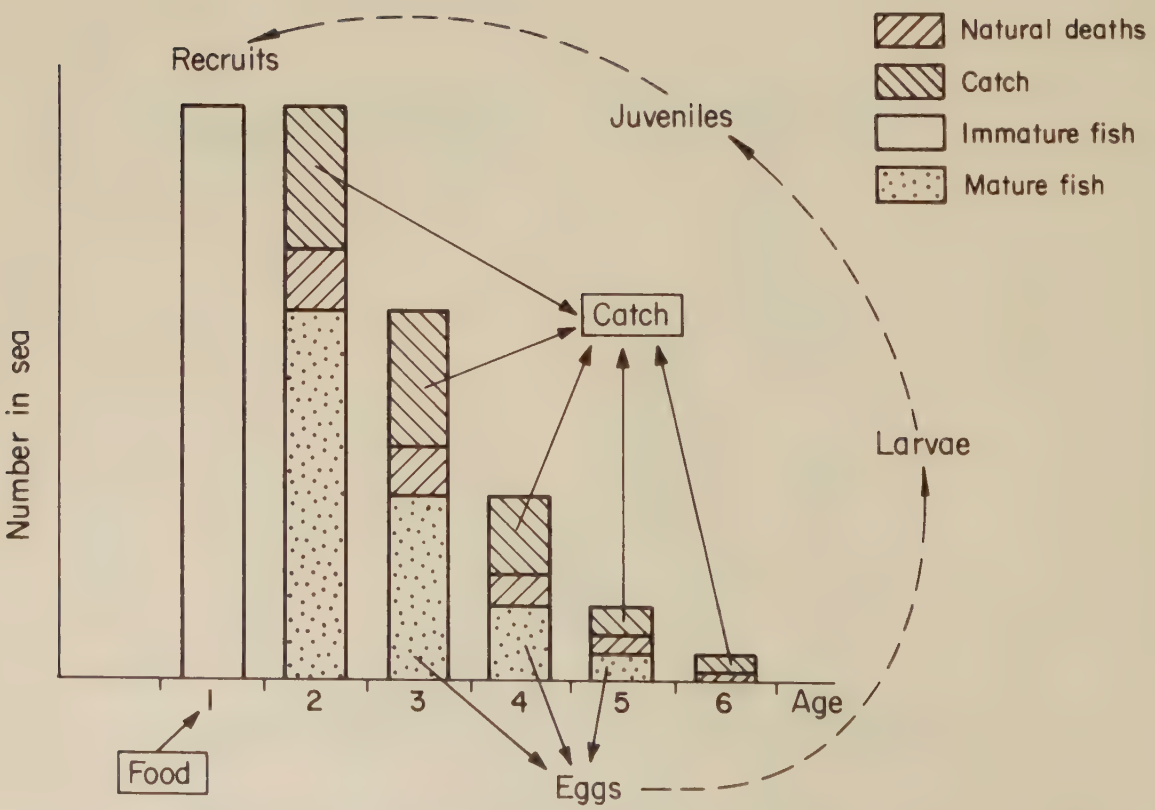


Fig. 8 The basic life history model

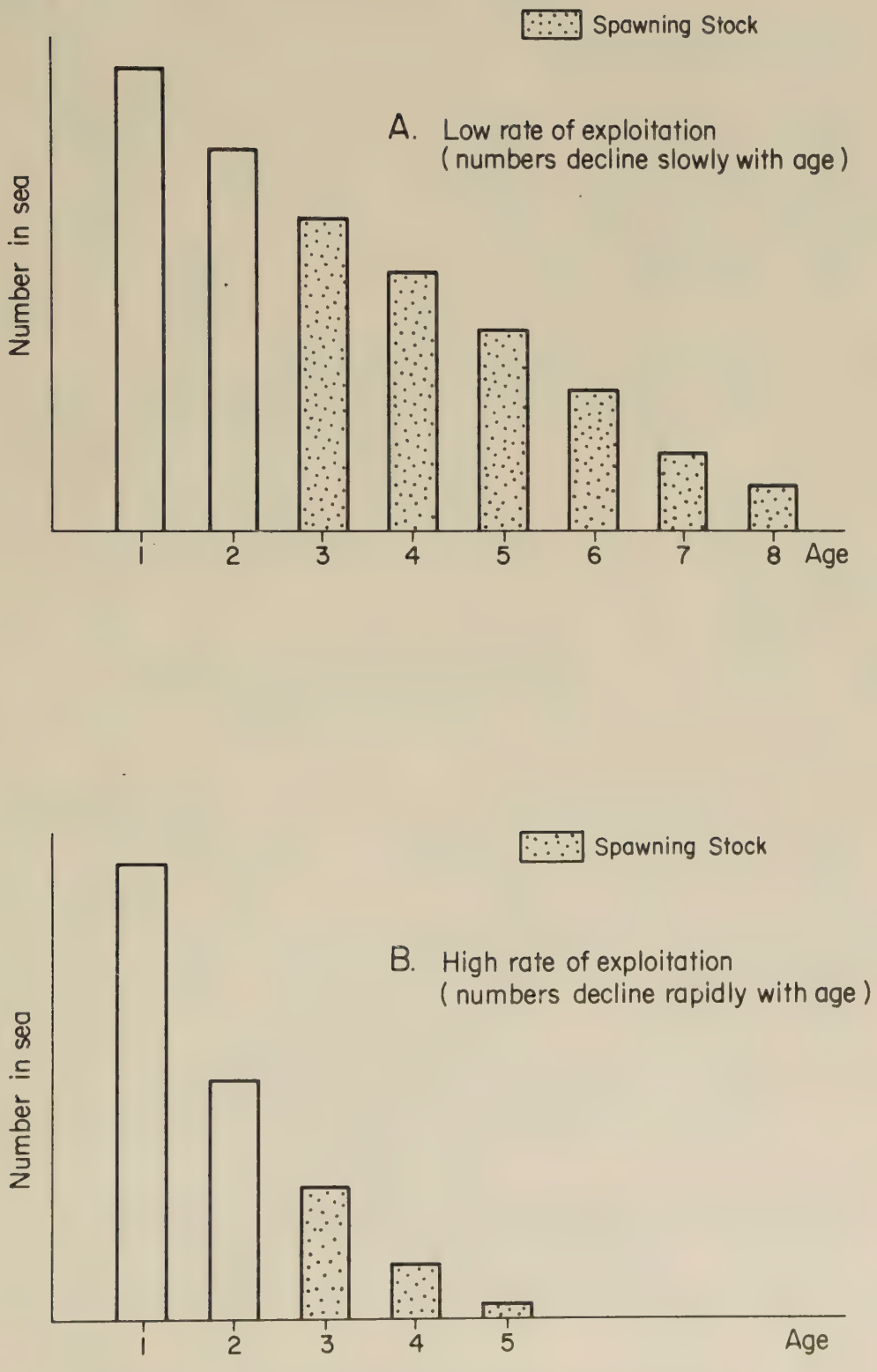


Fig. 9 Effect of exploitation rate on spawning stock

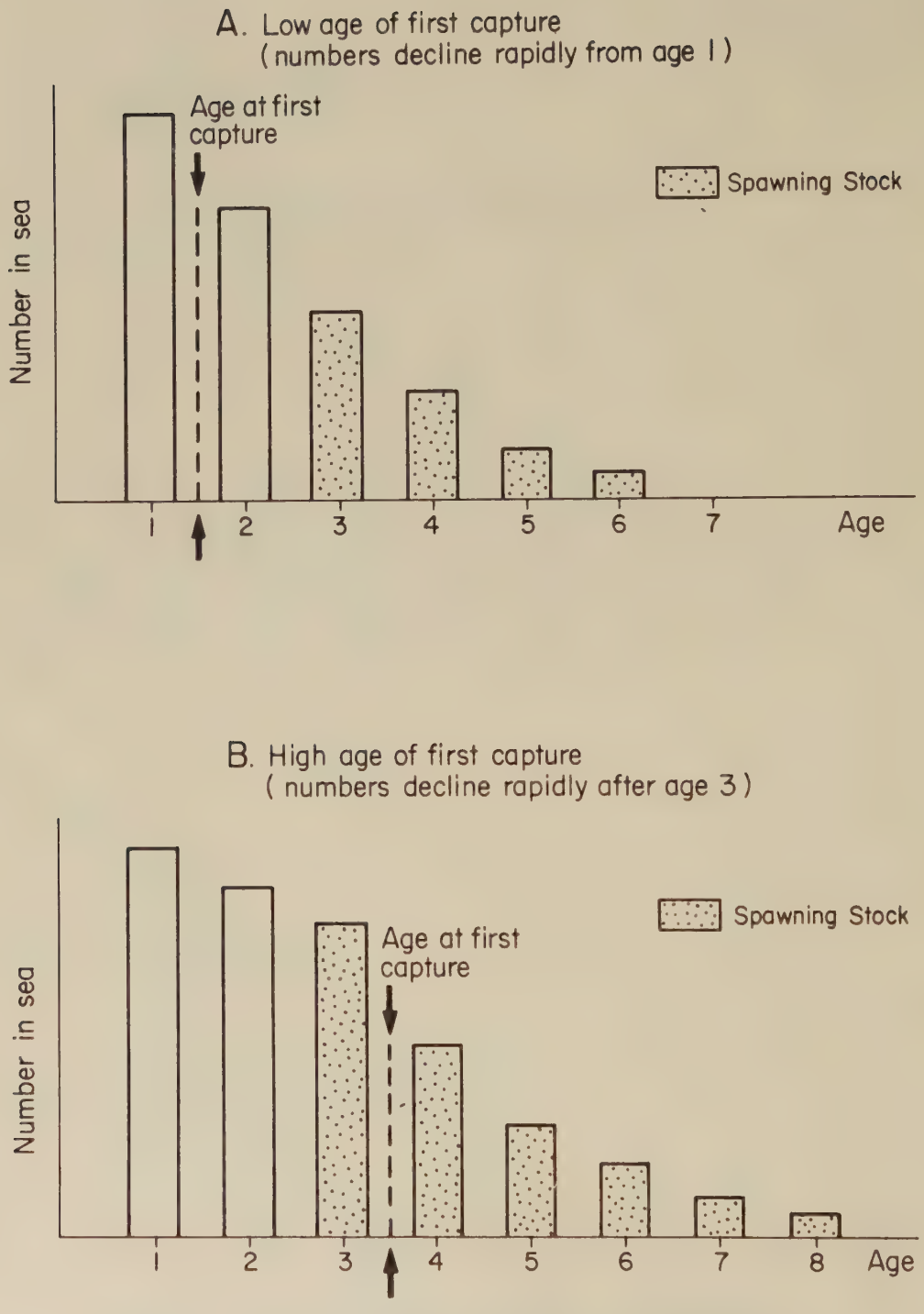
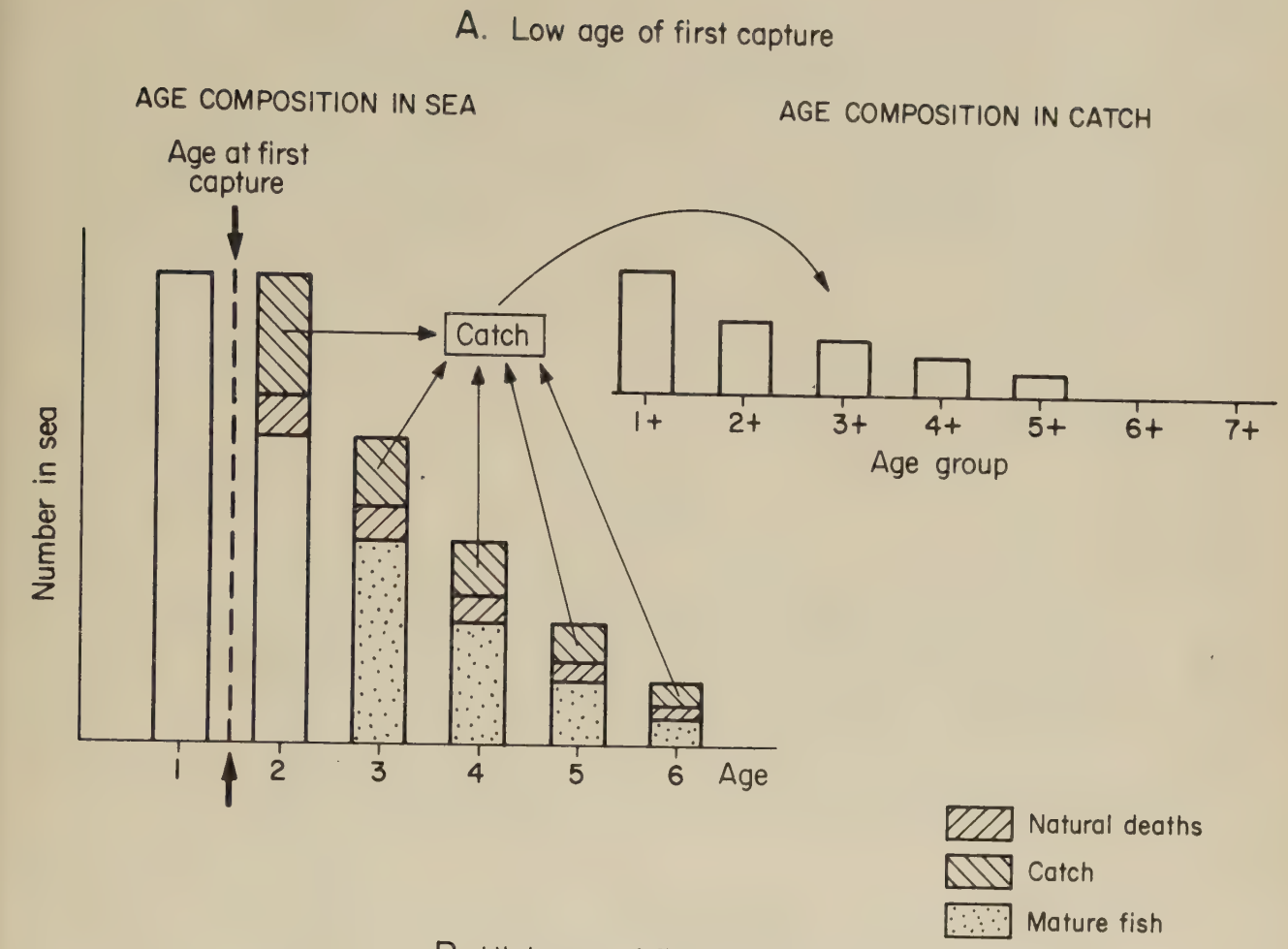


Fig. 10 Effect of age of first capture on spawning stock size



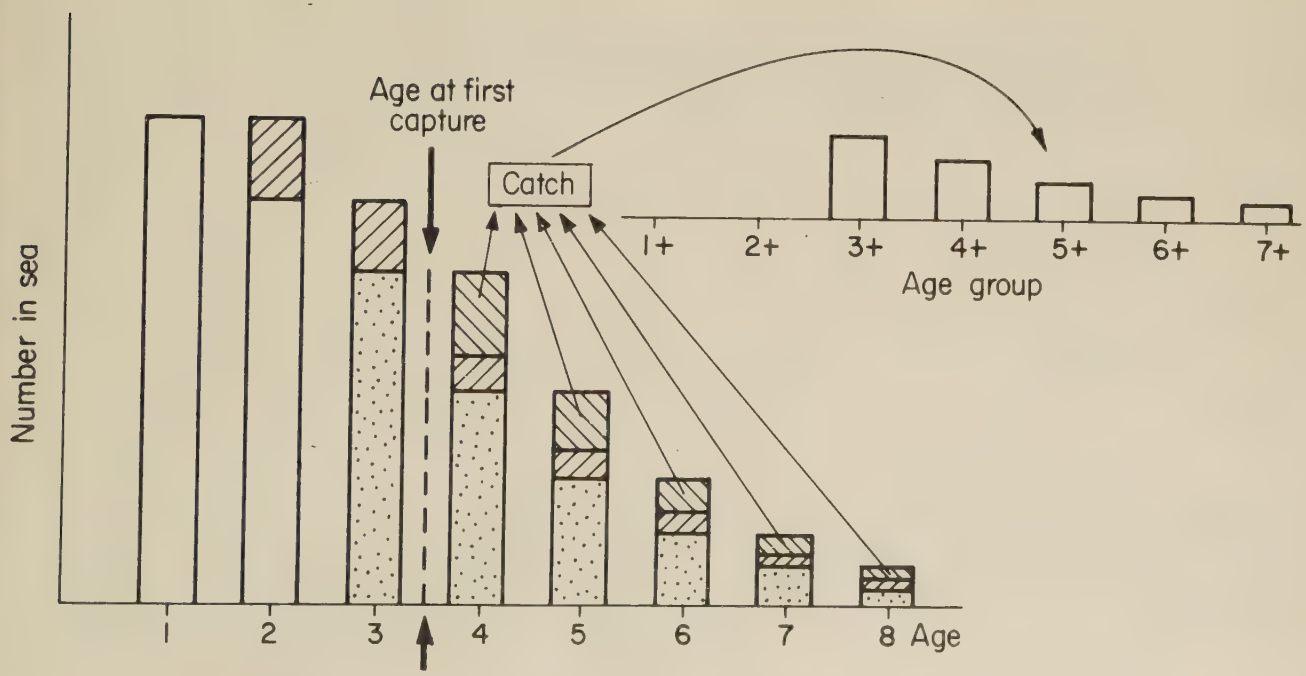


Fig. 11 Effect of change in age of first capture on the age composition of the catch

FISHING GEAR SELECTIVITY AND PERFORMANCE

by

David B. Thompson
SCOTED
Edinburgh, Scotland

M. Ben-Yami
Fisheries Technology Division
Haifa, Israel

Preface

The purpose of this paper is to draw attention to the broad aspects of fishing gear selectivity inasfar as it relates to fisheries management and to the measurement of fishing effort. It is not intended to provide a detailed or scientific analysis of selectivity, rather to give sufficient information for discussion of aspects of fishing gear performance that are of interest to fishery managers.

Selectivity is understood here as the capacity of any method or gear type to capture certain fractions or sections of the fish population whether grouped by species, age, size or behaviour, and to exclude others.

Too often gear selectivity has been viewed only in the very narrow sense of mesh selectivity in the cod-end of trawl nets. This paper takes a much broader view and treats mesh size as a rather minor aspect of total gear selectivity.

Some suggestions are made as to the usefulness and feasibility of management measures based on limitations of fishing gear size type or specification. It is hoped that they, and the general information contained, will be of some help to those involved in the formulation of fisheries legislation.

1. DEVELOPMENT OF FISHING GEAR AND METHODS

1.1 Chief gear types in use 1900-1940

In the early days of fishing and up to World War II, most commercial fishermen had a market for only a few species of fish. As a result of this, the types of gear and the methods they used were extremely selective. They were selective both as to species and as to size of fish taken. Most fishing boats were single-purpose units fishing practically all the time for one species and for fish above a certain size within that species. Some of the common vessels and gear types of the pre-war era are listed below together with the principal species sought.

Vessel	Gear Type	Fish Sought	Area Fished
Steam Drifter	Drift net	herring	N.E. Atlantic
Long Liner	Baited long lines	cod & halibut	N. Atlantic & N. Pacific
Otter Trawler	Granton trawl	cod & haddock	N. Atlantic
Danish Seiner	Bottom seine	plaice & cod	North Sea
Hand Liner	Hand lines	cod	Lofoten, Greenland, etc.
Pareja Trawler	Pair trawl	hake	Deep water, N.E. Atlantic
Lobster Potter	Lobster creel	lobster	Inshore waters
Ring Netter	2-boat ring net	herring & mackerel	Sheltered waters
Tuna Clipper	Pole and Line	skipjack, bonito, tuna	E. Pacific & C. Atlantic
Purse Seiner	Purse-seine net	sardine & herring	E. Pacific & W. Atlantic

It was relatively easy to control the fishing effort of the above vessels because many of them were working for one kind of fish and their gear in most cases could not be economically used to catch other species. The nearest thing to a multi-species fishery was bottom trawling, but even there a handful of species dominated the catch, especially in the higher latitudes where the bulk of fishing took place. Fish markets could not cope unexpectedly with less familiar species and there was little incentive to diversify. For most fishermen in the North Atlantic there were only two species that really mattered and these were herring and cod. Under that sort of situation one could fairly easily control the size of fish caught by regulating a minimum mesh size for drift nets and trawls or minimum hook size for long lines.

1.2 Main gear types now in use

The situation regarding fishing effort has altered radically since the war as a result of enormous advances in fishing technology coupled to a considerable increase in and diversification of fish markets. Today, two types of fishing gear account for the bulk of the fish catch in most countries in temperate regions. These two gear types are the trawl net and the purse seine. But within each type there exists a multitude of variations and sub-types which make simple analysis all but impossible. For instance, we could categorize the main trawls and seines as follows:

Otter Trawls	Trawls Without Otter Boards	Purse Seines
Smooth-ground Bottom Trawls	Beam Trawls	Two-boat Purse Seines:
Bobbin-rigged Otter Trawls	Double Rig Beam Trawls	Menhaden Seines, etc.
High-opening Bottom Trawls	Danish Seines	Lamparas & Ring Nets
Semi-pelagic Otter Trawls	Scottish Seines	Single-boat Purse Seines:
Midwater Trawls	Japanese Bottom Seines	Herring Seines
Single Shrimp Trawls	Bottom Pair Trawls	Mackerel Seines
Double-rig Shrimp Trawls	Midwater Pair Trawls	Capelin Seines
Twin-rig Shrimp Trawls	Bottom Pair Seines	Tuna Seines, etc.

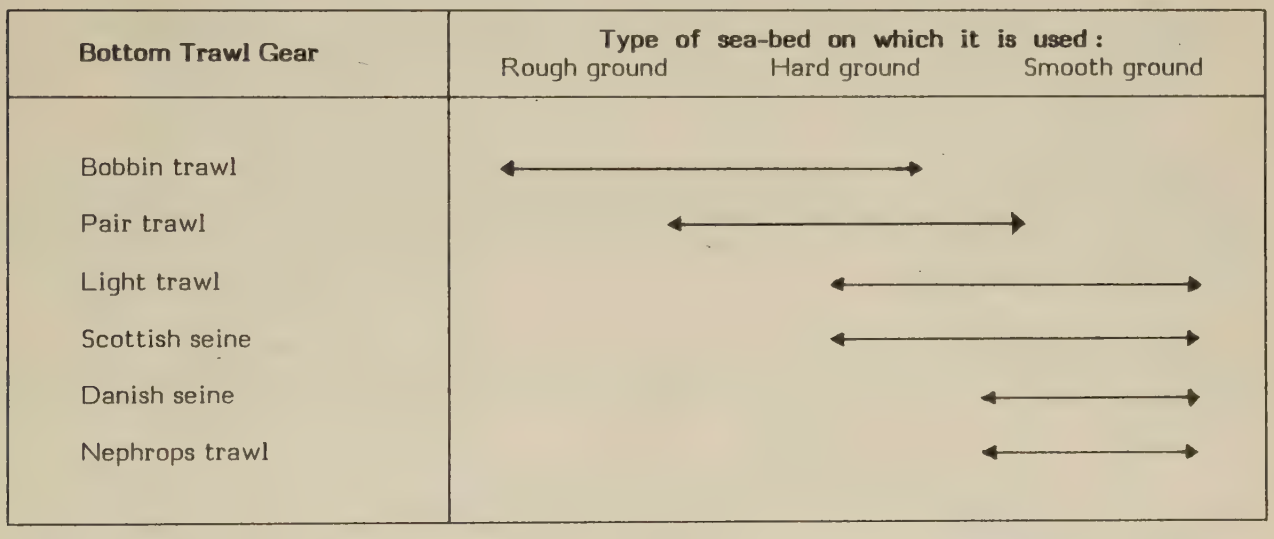
1.3 Purse-seine use and adaptability

Purse seines tend to be used for a single species of fish and the trawls for a variety of species. There are some purse-seine fisheries where a variety of species are taken, but these are mostly associated with light attraction or the use of fish aggregation devices. Salmon purse seines and tuna purse seines are not really suitable for the capture of other species.

However, although a North Sea purse-seine skipper might use his net chiefly to catch herring and/or mackerel, he might just as easily capture schools of sprat, capelin or pilchard. Provided that the other fish were available and that a market for them existed, this could happen. The fishermen's main concern in switching from one species to another would be that the mesh was small enough (to avoid gilling) and that the net was deep or shallow enough for the grounds and the schools of fish in question.

1.4 Range of species caught in bottom trawls

With trawl nets the situation is more complex. The net types listed have a basic selectivity related to their design and to their use. But they are all used on the sea bed and for the same general group of species. Taking just six of the bottom trawls used in the North Sea, we might illustrate how their use and effect overlap with each other, as follows:



Although they are all bottom trawls utilized chiefly for demersal fish, the proportion of different species caught varies as a result of the net design, the techniques used and the grounds fished. Note that the catch composition would still be different if all these trawls were used on the same grounds at the same time.

Relative proportions of different species taken by Trawl Nets in the North Sea - 1980

Kind of Fish	TYPES OF GEAR					
	Bobbin trawl	Pair trawl	Light trawl	Scottish seine	Danish seine	Nephrops trawl
	(%)	(%)	(%)	(%)	(%)	(%)
Cod	31.0	45.5	24.0	20.0	53.4	8.3
Haddock	32.7	21.9	25.6	44.2	14.8	3.0
Whiting	15.7	12.8	27.2	24.5	3.7	10.8
Saithe	13.2	14.9	3.5	1.1	0.5	2.0
Plaice	0.4	0.35	3.4	3.2	18.7	1.6
Dogfish	1.7	0.9	3.2	1.6	2.6	2.4
Monks	0.8	0.7	3.4	0.9	0.2	3.2
Lemon sole	0.6	0.5	2.1	0.9	2.4	2.3
Skate	0.8	0.25	2.1	0.9	0.3	2.3
Nephrops prawns	-	-	1.8	-	-	59.3
Other species	3.1	2.2	3.7	2.7	3.4	6.5
Total :	100.	100.	100.	100.	100.	100.

Source : Sea Fisheries Statistical Tables, England & Scotland, HMSO, 1973 & 1980

From the percentages of different species caught by each of the six bottom drag nets, we can see that their relative effectiveness varies considerably. Taking the closest of the above values for each species and the most variant, we can calculate the difference in relative effectiveness of the gear types as follows:

(times by which one gear may outfish another)

		Ratio			Ratio
Cod	:	0.03 - 5.0	Dogfish	:	0.06 - 3.5
Haddock	:	0.17 - 8.0	Monks	:	0.14 - 17
Whiting	:	0.12 - 7.5	Lemon sole	:	0.14 - 4.8
Saithe	:	0.12 - 30.0	Skate	:	0.12 - 7.0
Plaice	:	0.06 - 5.5	Prawns	:	300 +

These values reflect the difference in performance during one year only, but are sufficiently diverse to make the point that different types of trawls are selective in different ways. The selectivity of trawl nets is further dealt with in Sections 3.1 and 3.2, and 5.1 to 5.4.

1.5 Midwater trawl use

Midwater trawls are used to catch fish concentrated in schools or in layers anywhere from about 10 metres below the surface to about 10 metres above the sea bed. These concentrations consist mostly of fish of one species, and one size or age group. Herring, mackerel, sprat, anchovy or sardine may be taken by midwater trawls. The fishermen are usually looking for one particular species and they would have a fair idea from the echo-recordings, the place, time, depth and behaviour of the school, what species it consisted of. There is little selectivity in the trawl itself, apart from the size of the bag and codend meshes which are usually small in any case.

Midwater trawls pulled by more powerful vessels may catch faster-swimming, better-quality fish at times than nets towed by smaller boats. But if a layer of fish consists of two species, say herring and mackerel, or herring and pilchard, any midwater trawl towed through them is likely to capture both.

2. TROPICAL AND MULTI-SPECIES FISHERIES

2.1 Range of species and sizes of fish

In a multi-species fishery like the North Sea bottom trawl fishery, three species comprise over 75 percent of the catch. In many tropical fisheries one would count ten or twenty most prevalent species before totalling 75 percent of the total trawl catch.

If it is difficult in the North Atlantic to manage stocks of cod, haddock and whiting mingled together and caught together, how much more complex is it to manage three or four times as many species. This is a major dilemma facing fishery managers in the warm water countries.

In most developing countries all fish caught can be marketed, whether large or small, mature or immature. There is little incentive for any fisherman to throw juvenile fish back into the sea. The range in size and shape of fishes caught is such that any mesh restriction to limit capture of immature fisih of one species is bound to result in the loss of many mature fish of another species.

2.2 Selective types of gear

However, of fishing gear types and methods used in the tropics, some are extremely species selective. Even in waters where other species abound, their use does not create a complex management problem. The main selective gear types are listed below.

SELECTIVE TYPES OF GEAR

Gear Type	Species Sought	Other Fish Taken
Pole and line	skipjack & other surface tunas	almost none
Midwater trawl	mackerel or sardine	very few
Squid jig	squid	very few
Drift net	small tuna, salmon, barracuda	occasional shark
Tuna long line	large tuna	billfish & some shark
Scoop net	fry of milkfish, shrimp, grey mullet	very few
Trolling line	tuna species, jacks, mackerel, dolphinfish	no undesirable fish
Shellfish dredge	clams, scallops, oysters	starfish, sea urchin, flatfish
Tuna purse seine	tuna species	porpoise occasionally
Saury lift net	saury	almost none

2.3 Less selective gear types

Fishing gear and methods which are less selective include most of the demersal fish trawls, the seines and lift nets used in conjunction with light attraction or FADs, and many of the artisanal traps, lines and tangle nets. They are listed below.

LESS SELECTIVE GEAR

Gear Type	Main Species Sought	Less Desired Species Caught
Lift net *	sardine, mackerel, anchovy	bait fish, juveniles
Hand line	snapper, grouper, bream	shark, eels, ray
Bottom trawl net	demersal species & shrimp	trash fish, dollarfish, juveniles
Trap net	most edible species	shark, eels, stonefish
Purse seine *	tuna, sardine, mackerel, anchovy	small tuna & juveniles
Bottom Gill net	most edible fish & shrimp	ray, shark, jellyfish
Beach seine	any edible species	starfish, jellyfish
Bottom long line	larger demersal fish	eels, dogfish

* Used with light attraction or FADs

3. GEAR SELECTIVITY

3.1 Selectivity of Trawls by Design

Trawl nets and bottom seines possess an initial selectiveness owing to their particular design and mode of operation. A mesh size limitation would vary considerably in effect from one type of trawl net to another. It is important therefore to consider gear selectivity and performance before we begin to think of mesh sizes and their effect.

Take a herring vinge trawl for example and two other bottom otter trawls like the granton trawl and the shrimp trawl. All use otter boards, all are on the sea bed throughout the duration of the tow and all have the same basic structure of wings, square, bellies, bag and cod end. But their performances differ as much as those of a racing car, a truck and a tractor. All three nets could be fishing in the same area, yet the vinge trawl might take only herring, the granton trawl only demersal fish and the shrimp trawl primarily shrimp or prawn. Mesh size has little to do with this species selection. It is a function of other aspects of gear performance - speed of tow, headline height, ground contact, flow of water through the body of the net, otter door spread, length of ground-cables, and so on. The vinge trawl would have the smallest mesh in the cod end, yet it would take no cod, haddock or shrimp. The shrimp or prawn trawl would have a smaller mesh than the granton trawl yet it would capture only a small proportion of the bigger fish the granton trawl would take. To imagine that in these cases the size of mesh controls the size of fish caught would be as simplistic as to think that the respective speeds of the racing car, truck and tractor were determined by the size of their wheels.

In contrast to the trawls designed to capture one species or group of species, there are the multi-species trawls or combination trawls which take a great variety of fish. The North Sea prawn and fish trawl is a combination net designed to capture Nephrops norvegicus or Norway prawns, plus demersal fish like cod, haddock, skate, monks, plaice and lemon sole. Most bottom trawls in the tropics and sub-tropics are multi-species trawls taking fish which vary greatly from each other in size and shape. There is no common selectivity factor and no common minimum size or length for the various species. For these fisheries, a mesh regulation is at best an inadequate means of reducing juvenile mortality. It can be aimed only at the smallest of the main commercial species.

3.2 Selectivity by area swept

Many types of bottom gear depend on the area of sea-bed swept for their effectiveness in fish capture. Ropes, wires, cables and bridles are used to herd fish in the direction of the net. It would be uneconomic in terms of gear and power necessary to sweep such large areas with walls of netting.

Several species of fish respond to herding by ropes, and possibly just as many do not. Generally speaking, the demersal fishes of temperate waters are vulnerable to this type of gear while crustaceans and most pelagic fishes are not. There are several technical, environmental and behavioural reasons for this. Fish respond, not just to the approach of ropes and cables but also to the noise or vibration of the otter boards, and to the clouds of mud the boards leave behind. When the angle and the speed are such that the expanding trail of mud-cloud just touches the ground cable or sweep lines, then for many demersal fishes the herding effect is maximized; this applies only to trawls utilizing otter boards. Danish seiners and pair trawlers are able to herd fish effectively without disturbing the sea bed unduly.

The species that do not respond to herding by ropes include practically all of the shrimps and prawns, and most of the clupeids and mackerels. Trawl nets designed to capture shrimp have a wide but low net mouth and extremely short cables or bridles. Trawl nets for clupeids and mackerels have very large net mouth openings. To make the net mouth as big as possible without creating too heavy a towing load, large meshes are used. These meshes are big enough for the fish to swim through with ease, but this does not happen if the net is properly constructed. So pelagic species while they do not respond much to ropes or wires, will be guided by sheets of tight netting even if the mesh sizes are very large.

Examples of gear types which depend primarily on sweeping a wide area of the sea bed are listed below:

Bottom seines
(beach seines, Danish seines, Canadian pair seines)

Pair trawls
(bottom pair trawls, utilizing long warps and cables)

Otter trawls with Vigneron Dahl gear
(long cables inserted between the otter boards and the net or bridles)

Fishing gear which does not rely on herding fish from a wide area on each side of the trawl net is mainly used to catch shellfish. Some common examples are listed below:

Shrimp trawls	:	double rig and single rig
Nephrops trawls	:	except combination nephrops/fish trawls
Lobster trawls	:	used offshore in deep water, N.E. USA
Beam trawls	:	for flatfish, shrimp and sole
Dredges	:	for scallops, clams and oysters

Midwater trawls are used almost exclusively on schooling fish or scattered layers of schooling fish, and skippers always aim to tow the net directly into or through a school or layer. There may be some scaring effect from otter boards, weights, bridles or kites, but it can hardly be considered a herding effect.

3.3 Effect of tickler chains and ground ropes

The ground rope of a trawl net has an effect on the amount or proportion of flatfish and shellfish that may be caught. A heavy groundrope will tend to scrape tightly on the sea bed while a lighter one may travel more gently over the ground. The degree of abrasion on the sea bed can also be controlled to some extent by the slackness of the lower wings and by adjustment of the lower bridle chains.

Tickler chains are often used to dig up the sand just ahead of the ground rope. This drives flatfish and some shrimps and scallops up into the mouth of the net. Vessels working for Dover soles may use several chains, each slightly shorter than the other and thus dragging a foot or so ahead of each other in front of the net. Worn chains or chains of softer steel or alloy are not so effective.

Beam trawls fitted with a series of tickler chains are extremely effective in capturing sole which other trawl nets might scarcely touch. This may not be a bad thing in itself as the sole which bury themselves in the sand might not otherwise be harvested in quantity. What may merit concern is the possible damage to other marine life on the sea bed, from the disturbance caused by this heavy gear.

3.4 Purse seines and ring nets

Purse seines and ring nets or lamparas are selective both by their use and their design. Most large purse seiners operate chiefly on one species like tuna, anchovy or salmon, or on two or three species like herring, mackerel, pilchard and sprat.

With purse seines, one is dealing with schooling fish of one species or with a body of mixed fish attracted by light or FAD. Most purse seine skippers know what species of fish they are setting on, at least 90 percent of the time, from the nature of the echo-traces, the locality, time of year, and the behaviour of the school. Exceptions to this are the smaller light-fishing purse seiners in the tropics or sub-tropics. They take a very mixed catch of sardines, anchovy, horse mackerel, bait fish and some larger species like tuna and mackerel. Occasionally a lot of very young tuna are taken.

It has sometimes happened that a North Atlantic seiner, searching for herring or mackerel, has netted a school of whiting or cod. But this occurs so rarely and in such unusual circumstances that it does not present a management problem.

Mesh sizes are important to a seiner skipper mainly because he wants to avoid gilling fish whatever happens. A mesh that is too small poses a very minor problem compared with one that is not small enough. If a catch of very small fish is taken (and schools tend to be made up of fish of one size) then it is a simple matter to let them go while they are still alive. There is much more likelihood of fish surviving if released from a purse seine than from a trawl net after it has been hauled up. Both the density of fish in the bag, and the sudden pressure decrease from the seabed to the surface, can cause mortality before the cod end is released.

Purse seines in Lake Kinneret carry a filter panel at the top of the bunt to permit the escape of small fish. The filter panel mesh is 20 to 25 percent larger than the other seine meshes. Small fish are allowed to swim through the panel before the catch is dried up in the bunt. Some fish are gilled but they can be shaken out of the filter netting. This could hardly be done if the larger mesh was used throughout the body of the net.

An interesting example of how a purse seine can be made to be species-selective is seen in the United States tuna fishery. Schools of dolphin or porpoise were sometimes netted along with tuna and there was considerable pressure from conservationist and environmentalist groups to prevent unnecessary slaughter of these animals. The solution adopted involved a "backing" operation and the use of purse seines fitted with shallow escape lips for the porpoise schools. With skill and practice it became possible to release the dolphins alive without losing any of the valuable tuna catch.

3.5 Selectivity of gill-nets

Gillnets are obviously size selective and will seldom capture fish small enough to swim through the meshes. Fish too large to be gilled properly will sometimes be entangled in the netting but this is not always so.

In the early days of the Lake Kariba fishery, some of the indigenous Zambesi fishes grew to remarkable sizes. Tilapia mossambica was one of these and being highly marketable it was much sought after. In 1961 the gillnets used were of 4 and 5 inch mesh chiefly as these were the sizes used in Lakes Mweru and Bwangwelu. During 1962 and 1963 nets of $5\frac{1}{2}$ and 6 inch mesh were successfully

introduced and these caught large tilapia which the other nets rarely took. Nets of $6\frac{1}{2}$ and 7 inch mesh were then tried out and even larger fish taken, but their numbers were much smaller. Experimental nets of $7\frac{1}{2}$ and 8 inch mesh were also tested but these caught no fish at all. The experience is mentioned to indicate how large fish can avoid capture by a gillnet. Fishermen can get over this to some extent by hanging their nets very loosely.

Another rarely mentioned aspect of gillnet selectivity is that inactive fish are seldom caught. Just as a long line will only hook hungry, feeding fish, a gillnet will only capture fish that attempt to swim through it. During cold weather or in the dry season, fish in most African lakes become very inactive. Their metabolism slows down to the point where they hardly move or eat. During such periods they will rarely be caught by a gillnet, unless they are driven in as happens in some fisheries. Fishermen in northern Newfoundland and Labrador have observed cod behaving in this way in small bays or creeks, at certain times of the year.

In temperate waters, gillnets tend to be used to capture a single species - herring, cod, salmon or plaice. In the tropics a multitude of species are caught. Thus a mesh restriction to protect juveniles works well in temperate fisheries or in a single species fisheries but is rather pointless elsewhere.

Since the decline of drift netting for herring, the main gillnet fisheries in temperate waters, have been those for salmon and for cod. The bulk of gillnet fishing in the world today occurs among the small-scale fisheries of Asia and Africa. There, such a wide range of species and sizes is taken that control by mesh restriction is out of the question in all but a very few isolated cases.

4. SELECTIVITY OF FISH ATTRACTION METHODS

The three main methods of fish attraction are by light, by bait, and by floating rafts and artificial reefs. Each method is selective under different conditions. The selectivity is the product of the combined effect of the attractant, the fishing gear, the location and the method or application. Note also that secondary attraction occurs. Larger species come to prey on small fish congregating around the attractant.

4.1 Light attraction

Lights are used throughout the tropics and sub-tropics to attract fish for capture by purse seine, ring net or lift net. Light attraction is not much used in temperate waters owing to negative or unpredictable reaction by fish. In many cases there juveniles are attracted and mature fish repelled or left unaffected.

Most of the small pelagics in the tropics display positive phototaxis. These include sardinella, anchovy, saury, small mackerel and bait fish. Squid are also attracted to light but prefer to stay in the fringes of the illuminated area. Larger fish are attracted by the concentration of small fish, and by their movement or increased activity in the presence of light.

Thus catches made with light attraction and seines or lift nets tend to be of mixed species of fish. Exceptions to this are squid which are taken by special jigs that would not catch other species, and surface swimming saury which are taken by stick-held dip nets in waters north of Japan.

Catch composition may differ from area to area. The same net and lights may catch different fish if employed over shallower or deeper waters.

In Lake Tanganyika, dagaa and ndakala sardines are taken along with perch and Nile perch. The dagaa of Lake Kariba are accompanied often in light-attracted catches by quantities of Alestes species. In S.E. Asia, sardinella, mackerel, scad, anchovy and tunas are taken together. Light-induced catches in the Mediterranean may consist of mackerel, pilchard, sardinella, anchovy, sprat, immature barracuda and occasional tuna.

Small light-sticks are now used on certain baited long lines, drop lines and traps. They are used on swordfish long lines and on hand lines and fish traps for large demersal species in places like the Caribbean.

4.2 Bait attraction

Bait is possibly the oldest means of attracting fish and it is still in widespread use today, particularly in traps and pots used for lobster, crabs, prawns and rockfishes. Longlining for cod, halibut, ling or dogfish in northern waters is coming back into use after a decline of some years. Tuna long lining is still practiced in the Pacific and Indian Oceans. Swordfish long lines are used off the eastern seabord of the USA. Small-scale fishermen in some parts of the world use bottom-set long lines.

Most of these methods are fairly species selective. While one still gets crabs in lobster pots, skate on cod lines, and shark on tuna lines, they are the exception rather than the rule. The baited lines and traps can be considered to be selective in both attraction and capture. This is partly the case, of course, because they are set in areas and at depths where the fish sought are known to be present.

Live bait fish are used to attract schools of skipjack, bonito and other tuna for capture by pole and line. This is a very selective method, since the schools are detected visually first and since the fishermen can see what they are taking.

Some of the live bait used is itself caught by bait - a ground meal or powder made of cereal, fish or other protein. The use of this kind of bait is usually called "chumming" and it is normally selective in attracting only the small bait fishes needed by the pole and line vessels.

4.3 FADs and artificial reefs

Fish aggregation devices, or FADs for short, are used to attract pelagic fishes in the tropics. Tuna purse seiners and pole-and-line vessels fish around those anchored in deep waters off the islands of the Indo-Pacific. Smaller purse seiners and lift-net boats fish around FADs anchored in shallower waters nearer land where sardines and small mackerels may be found.

The FAD itself is a floating raft to which are attached strings of palm leaves or old ropes, netting or tyres. The attraction of fish to these devices is not fully understood. It may be partly for shelter or protection, partly for orientation, and partly to feed on the smaller fish or algae that accumulate there.

As with light attraction, a mixed body of fish is attracted to a FAD. Light or bait attraction is often used to supplement the drawing power of the FAD, or to draw fish in closer before capture. The small fish usually swim closest to the raft, and the larger ones further away. Big tuna may be caught by hand line many fathoms below a FAD.

Artificial reefs, as their name implies, attract mainly reef fish and crustaceans. They are installed on bare stretches of the sea bed where the natural habitat is poor. The artificial structure becomes a favourable habitat for many of these species. Although few of them have been constructed in northern Europe, fishermen there for many years have practised fishing close to rocks or wrecks where fish tend to congregate.

The selectiveness of fishing methods used in conjunction with attractants may be summarized as follows:

Very selective	:	Squid fishing with jigs and lamps Stick-held dip net and lights for saury Live-bait pole and line fishing for skipjack Chumming for small bait fish
Generally selective	:	Baited and/or lighted long lines Baited traps and pots Baited, trolling lines and hand lines

Less selective : Purse seining or lift-net fishing with the use of light attraction
Purse seining around FADs
Gill netting and hand lining around reefs and wrecks

5. EFFECTIVENESS OF MESH REGULATIONS

Minimum mesh sizes have been introduced in most well-developed trawl fisheries to reduce the fishing mortality of undersized or juvenile fishes. That small fish can escape through cod-end and bag meshes has been confirmed by numerous underwater films and observations. Whether the mesh regulation has a significant impact on the number of juveniles surviving to maturity is not always certain. Other factors must be examined, and these include the post-release mortality rate, the percentage of juveniles that would be caught in trawls, vis-a-vis the total juvenile population, and periodic natural fluctuations in the stock of fish in question. An important factor in fisheries where adjoining countries harvest a common stock of fish, is the existence and enforcement of similar legislation in each country concerned. There is little incentive for one state to protect young fish if its neighbour is harvesting them regardless.

As trawl nets differ greatly in performance, we will examine the effects of minimum mesh sizes on three main types of bottom trawl: multi-species bottom trawls; bottom trawls for pelagic species; and shrimp trawls. Note that in each case the minimum mesh size applies to the bag and cod end only. The meshes in the wings, square and shoulders are much larger.

5.1 Bottom trawls for demersal species

These trawls are used all over the world, chiefly by inshore or nearwater vessels, but the variety of species caught tends to increase towards warmer waters. A further complication in the tropics is that very small fish are quite saleable on local markets. In temperate countries consumers tend to avoid small fish, so if these are caught they generally go for reduction to meal, oil or pet food.

In a temperate fishery most fishermen would accept a mesh restriction without much argument. There are two situations in which it might be resented. One concerns fish which owing to their shape tend to escape through meshes which would stop mature fish of a similar species. The whiting, Gadus merlangus, is an example of this. Though it resembles the haddock, Gadus aeglefinus, a mesh that would retain mature haddock would permit fairly large whiting to escape. Conversely, a mesh that would retain mature whiting might also retain immature haddock. Further legislation introduced to cope with this problem has involved minimum sizes for fish sold for human consumption. However, that does nothing to prevent numbers of small haddock being killed in order to capture mature whiting. In that kind of situation, if the mesh regulation aimed at haddock is obeyed, large quantities of mature whiting will not be caught. If it is infringed, or area by-laws introduced to permit smaller meshes, some immature haddock and other fishes will be destroyed.

The other situation concerns fisheries where the income from industrial fish (fish sold for conversion to meal, oil or pet food) is a significant portion of the gross earnings. This creates an incentive to keep as large a by-catch as possible. If the by-catch is pout, sand eels or sprat, little harm is done, but if it is young herring, whiting or haddock, then other fisheries could suffer. Legislation to limit the harmful effects of industrial fishing usually relates to the proportion of juveniles of other species in the by-catch. However, unless there is strict inspection, infringements will occur regularly, and this makes enforcement both troublesome and expensive.

In tropical and Mediterranean fisheries, bottom trawlers tend to keep all fish caught for human consumption, regardless of size. This results in the landing of many juveniles and the constant incentive to use small-meshed cod ends. A minimum mesh size regulation is thus difficult to enforce and if enforced it could result in the loss of many mature edible fishes like squid, lizardfish and wolf-herring. Further complications exist owing to the pelagic and semi-pelagic behaviour of many of the species. They can be trapped in seines or lift nets which do not have a mesh restriction. So immature fish escaping from a bottom trawl in the tropics may still be caught in another type of gear before they reach maturity.

5.2 Bottom trawls for pelagic species

These are mostly herring trawls and tend to be Scandinavian vinge trawls or high-opening semi-pelagic nets of the Polish or German type. Since they are used to catch herring, mackerel, sardine, sprat or sand-eels, they must of necessity use small-meshed bags and cod ends. When properly rigged and operating for the prescribed species these trawls take very little other fish of any description. However, it is possible to trim the gear in such a way that it will take demersal fish in quantity. This can happen when there are no herring or sprat around and the skipper wishes to make up a load of any kind of fish. However, as the mesh size remains the same, many immature white fish could be taken. These would either be dumped (dead) at sea or brought in for industrial use. The point is that once trawlers are permitted to use small-meshed bottom trawls for pelagic fish it is almost impossible to prevent their use on demersal stocks if the pelagic species are scarce.

5.3 Shrimp trawls

Three catch problems associated with shrimp trawls concern the by-catch of mature edible fish which is usually discarded, the capture and destruction of immature fish and the capture of juvenile shrimp.

The fish by-catch problem cannot be tackled by mesh size limitations, otherwise no shrimp would be caught. Separator shrimp trawls have recently been designed in an attempt to deal with the problem. In these trawls, much of the by-catch is separated from the shrimp and released before it reaches the cod end. But this necessarily involves some loss in shrimp catch, additional gear expense, and the inconvenience of handling and repairing a more complex net.

An alternative solution adopted by some states is to insist that the shrimp trawlers retain all the mature fish, or a significant proportion, and bring them back to port for sale on local fish markets.

Only the smallest juvenile fish will escape through a mesh size designed to retain shrimp. Whether the destruction of young fish by shrimp trawls is sufficient to merit concern is debatable. Many young fish are high swimming and shrimp trawls have low headline heights so the juvenile catch may not be excessive, but this could be determined only after proper investigations.

Many shrimp fisheries do not have even a minimum mesh size to protect juvenile shrimp. In tropical countries where small shrimp can easily be sold for human consumption and for making shrimp paste, there is not much motivation among fishermen to protect juveniles. Surprisingly, several such fisheries seem to have survived many years of intensive fishing with small-meshed trawls. The Malacca Strait fishery is an example of this.

A mesh restriction for shrimp trawls to protect juvenile shrimp would appear to be in the interests of all concerned, and would have few undesirable side effects. But enforcement would have to be strict throughout the whole area. The fish by-catch problem could not be tackled by mesh regulation, only by use of separator trawls, or by insisting that mature fish be preserved and taken back to port for sale. Unfortunately, both these solutions may be costly or difficult to enforce.

5.4 Other observations

Cushing (1974) states that "conservation by mesh regulation is least conservation because it is adapted to the smaller and numerous species like the haddock in the North Sea; larger species (for example, cod or turbot) are not necessarily conserved there as well as they might be."

When considering the effect of a mesh size one must bear in mind not only its dimensions but its shape when the net is being towed. The twine material also has an effect as has the accumulated weight and volume of fish in the cod end at any one time.

A further point about mesh size regulations concerns the ability of resourceful fishermen to get around them. Let us take a hypothetical case of a bottom trawler working for demersal fish in the North Sea. In his area the minimum mesh size is say 80 mm. This is fine for haddock and cod, but suppose the vessel encounters quantities of whiting, most of which can escape through an 80 mm mesh. What can the skipper do if he wants to get around the regulation? He could (a) change the cod end temporarily; (b) add a blinder or second bag and cod end over the first; (c) restrict the meshes in some other way so they do not open fully. Unless he was apprehended in the act of fishing with either modification, it would be extremely difficult after the event to prove any infringement of regulations.

There are in fact ways of accomplishing (c) which would probably not represent a breach of regulations at all, e.g. doubling the number of meshes in the cod-end circumference.

6. SUMMARY AND CONCLUSIONS

This paper was prepared primarily to outline the existing situation and to draw attention to problems rather than solutions. Some lessons appear to be obvious however and these are mentioned in conclusion.

The complexities of modern fishing-gear selectivity and performance are such that to attempt to limit the less desirable effects of fishing by legislating on the design, size or specification, of the gear used would appear in most cases to be scarcely worth the effort. Only after extensive and thorough studies can the full or precise effect of any modification be determined.

Nevertheless in isolated, well-studied cases, an enforceable mesh regulation may be a useful component of an overall management system. A size limitation on the depth and length of purse seines, pound nets or gillnets may also be useful in controlling effort in specific fisheries.

In other situations it may be more feasible and sensible to impose a complete ban on certain types of gear in given areas, or a limitation on the number and size of fishing vessels. If a size limitation is to be placed on fishing boats it would be much more practical and meaningful to make it a limitation on engine power rather than length or tonnage as has been often done in the past.

Any limitation or regulation by power must also be related to method of fishing, particularly active methods such as seining and trawling. Engine power has much less effect in vessels using passive systems like gillnetting and long lining.

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CONTROL OF THE AMOUNT OF FISHING BY CATCH LIMITS

by

J.A. Gulland
Marine Resources Service
FAO Fisheries Department
Rome, Italy

1. INTRODUCTION

The assumption on which the present Consultation is based is that a country (or a group of countries sharing a stock) has determined that in relation to national policies (economic efficiency, greater food production, etc.) the amount of fishing on some given stock is too high and should be reduced.

The simplified rationale behind such a decision is illustrated in Figure 1, which is a typical yield curve as given in numerous volumes and reports on fishery management. This gives the relation between sustained catch and number of standard vessels. The figure also shows the relation between the number of vessels and the abundance (biomass) of the stock. Without any regulation the economic long-term equilibrium is at the point A, where 125 vessels are catching 56,000 tons. A better state (according to the policies of the country) would be B, where, in the long-term, 76 vessels would catch 60,000 tons. Apart from an increased total catch, these 76 vessels should generate much profit, which could go into the pockets of (a limited number of) deserving fishermen, be siphoned off to central government or used in other suitable ways.

In principle there are several ways in which it can be determined that the fishery is being maintained close to the target point (e.g. by checking that the stock abundance is around 90,000 tons, or that only about 70 standard vessels are operating), and several measures by which the necessary controls can be applied (e.g. catch quotas, licence limitations, or various indirect measures). The same measure need not be used at all stages in the process. For example, it may be decided that the best long-term target is to maintain the spawning stock at 90,000 tons; that to do this the catch in 1983 should not exceed 60,000 tons, and this will be achieved by imposing a tax of $50 per ton on all landings, thus discouraging all but a few vessels from going fishing (the level of the tax being set so that just that number of vessels will consider it worth going fishing as is required, given the likely catch rates in 1983, to catch 60,000 tons).

If life were as simple as suggested by Figure 1, then the choice of measure for setting targets or controls would not be critical. Unfortunately, for virtually no fishery does Figure 1 give an adequate representation of biological reality, nor are the commercial and administrative facts of life such that deciding that the quota for 1983 should be 60,000 tons is sufficient to ensure that no more than 60,000 tons are caught. Among the few stocks for which Figure 1 is a reasonable (though not exact) representation of biological reality are whales. The history of whale management does not suggest that biological simplicity alone is a guarantee of successful management.

The choice of the appropriate measures (catches, effort, etc.) for setting targets and controls can be critical. Further, because the nature of the biological, economic, social and administrative complications vary greatly from fishery to fishery, the best measure is not the same in all fisheries but for each fishery has to be carefully chosen after looking at the particular condition of that fishery.

Nevertheless, a superficial examination of fishery management today would suggest that the only proper way of managing fisheries is through catch quotas. The apparently interminable discussions within EEC are concerned very largely with the value of Total Allowable Catches (TACs) and how they should be allocated. Some of the key phrases in the draft convention of the Law of the Sea - "The coastal state shall determine the allowable catch" (Article 61(1)) or "Where the coastal state does not have the capacity to harvest the entire allowable catch, it shall ... give other States access to the surplus ..." (Article 62 (2)) - imply that catch limits are the key to good management. This is far from being the case; later sections in this paper will show that in many situations attempting to control the

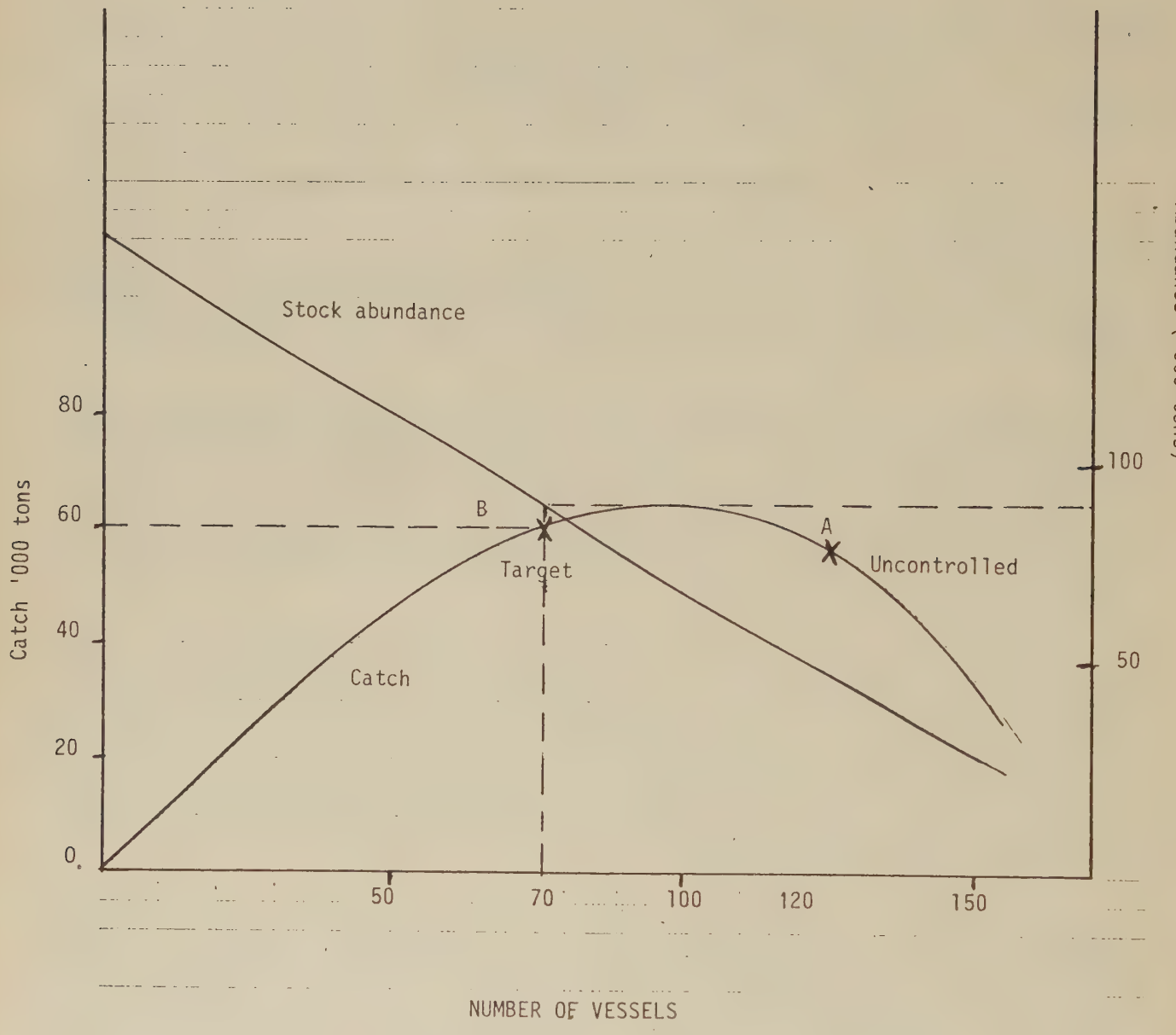
Stock abundance
Catch
Target
Uncontrolled
A
B
Catch '000 tons
Abundance ('000 tons)
NUMBER OF VESSELS
0
20
40
60
80
100
50
50
70
100
120
150

Figure 1

fishery through catch limits is a second - or third - best method. Also, as shown in another paper, the so-called "surplus" is like a unicorn - very nice in theory and in illustrations of the ideal life but seldom seen in real life. (These comments are, of course, no criticism of the UN Conference on the Law of the Sea, in which fishing was a relatively minor item. Within national delegations the fishery experts were concerned principally in ensuring that their national interests were not hurt. For this purpose meaningless or indeterminate phrases often served well. The only ones among those attending UNCLOS whose prime interest was to see that the text provides as good a framework and guide as possible for rational fishery management and development were some of those from international organizations. These were attending as observers and were relatively powerless to influence the outcome.) To understand why catch quotas have achieved their current prominence, and thereby make it easier to come to a fresh evaluation of the relative strengths and weaknesses of different approaches, it is necessary to give a short historical review.

2. SOME HISTORY

Regulation of important commercial fisheries by means of catch quotas goes back nearly half a century to the North Pacific halibut fishery (Skud, 1973) and, immediately after the second World War, Antarctic whaling (Allen, 1981). However, the key period, when the attention of fishery scientists and administrators became focussed on the control of fishing effort, and when it became commonly accepted that the proper way of doing this was by catch quotas, was in the 1960s, and especially in the two North Atlantic Commissions (NEAFC and ICNAF).

By the 1960s, regulation of the size of trawl meshes had been in force in several parts of the North Atlantic for some time. It was clear that while such regulations did give benefits, there were limits to how far they were effective in multi-gear, multi-species fisheries, i.e. the conditions in most of the area except some of the most northern parts (Bear Island, Labrador) which were nearly pure trawl fisheries for cod. It was also clear that such regulations could do little (and then only in the short- to medium-term) to tackle the economic problems of excess effort and hence excess costs. ICNAF in particular was active in promoting basic studies of the problem (e.g. Templeman and Gulland, 1965; ICNAF, 1968). These studies showed that there were two basic choices that need to be made: (a) whether the amount of fishing should be measured and controlled in terms of catch or effort (e.g. number of days at sea), and (b) whether there should be a single global quota or whether there should be allocations to countries of specific shares in the total quota.

The second question was easily answered. Both theoretical studies and practical experience in the fisheries for whales and halibut showed that without allocation there would be a scramble for the quota (e.g. the "Whaling Olympics") and most, if not all, the potential economic benefits would be dissipated. Though a single unallocated quota still continues to be used in some fisheries, e.g. the Eastern Pacific yellowfin tuna, horse mackerel in the South-East Atlantic, these are exceptions. In practice the system of exemptions used in the tuna fishery meant that there were de facto allocations, with the amount left after the exemptions were dealt with being in effect the US allocation. There are doubts about the effectiveness of the ICSEAF measures.

To answer the first question - measuring the amount of fishing in terms of catch or effort - it was therefore necessary to look at the implications for allocations, as well as the other factors such as the constancy of the relation between catch or effort on one hand, and fishing mortality on the other. In the conditions of the North Atlantic Commissions this tipped the balance very clearly towards using catch.

Catch allocations are easily understood; if one country has a quota of 50,000 tons and another 100,000 tons, the second is, in at least one obvious sense, getting twice the benefits of the first. Whether the real benefits are twice as much is another matter, depending on the ways in which the countries use their quotas and manage their fisheries to reduce costs and increase the gross returns (e.g. by timing the landings so as to get the best prices). Everyone concerned - the ordinary fisherman as well as the administrators round the negotiating table - could see what was happening to their shares, in absolute terms and relative to others. In contrast, with the variety of vessels and gears involved, effort allocation was viewed as complicated and difficult to understand. It is far from clear what combination of numbers of Portuguese dory vessels, English wet-fish trawlers, and Russian factory ships would be needed to achieve a target fishing mortality and a fair allocation between countries.

Further, and this was a point given some emphasis in the North Atlantic Commissions, the efficiency of each of these groups will change with technical improvements, and change by different amounts. Thus the target efforts, in total and for each country, would have to be continuously changed. It would be difficult scientifically to determine the necessary change but even more difficult, politically and administratively, to get the necessary changes agreed to, especially to get a country whose fleets have increased their efficiency a lot to agree to a greater than average reduction in its allocation in terms of nominal effort.

It was recognized that the target catch would have to be altered from year to year to allow for changes in stock abundance (e.g. presence of a good year-class). However, it was felt that these adjustments - that did not have to involve differential adjustment to national allocations - could be dealt with. In the context of the main fisheries being discussed - principally the northern cod fisheries - this was reasonable. In most of the stocks the fish are long-lived; typically fish recruit at three to five years old, but do not make their biggest contribution to the fisheries until perhaps six to eight years old, and some of the fisheries on spawning fish depend on even older fish. Thus the strength of most year-classes in the fishery could be estimated from their occurrence in the commercial catches of previous years. The exceptions - the one or two youngest year-classes - did not contribute significantly to the catches and even these, it was believed, could be estimated if necessary by research-vessel surveys of the pre-recruit fish.

To a large extent these expectations have been fulfilled. Allocation of national shares of some Total Allowable Catch has been established as a workable method of controlling the total amount of fishing in a multi-national fishery. Scientists have found it possible to agree among themselves on the values of the TAC to be set each year and these recommended values of the TAC have been, at least in a good number of cases, approximately correct in terms of the state of the stocks and the objectives of the managers. The fishing industry and administrators have learnt that it is convenient to follow the recommendations of the scientists on the value of the TACs.

There have been exceptions. The scientific estimates of the appropriate TAC have sometimes been in error, and the countries have sometimes been able to reach agreement only by agreeing on a TAC in excess of the scientific recommendations. On occasion these exceptions have been serious, e.g. in relation to some herring stocks (Saetersdal, 1980). One cause of scientific error is relevant to the present discussion because it arises from control by catch, rather than effort. To calculate TACs it is common practice to use Virtual Population Analysis (VPA). In this the choice of the terminal F (i.e. the fishing mortality assumed to be occurring in the last year for which data are available) is critical (Pope, 1972). If, in say 1982, when the TAC for 1983 is being calculated on the basis of 1981 data, the value of F for 1981 is under-estimated, this means that the stock in 1981 will be less than one thought and the catches during 1981 will take a higher proportion than expected of this smaller stock. Thus the degree of over-estimation of the stock at the beginning of 1983 (and of the TAC for 1983) may be considerably greater than the original degree of under-estimation of 'terminal F'.

However, even with these exceptions, the events of the past years have confirmed that catch quotas were appropriate to the conditions of the multi-national fisheries. Nevertheless, the extent to which attention of managers and others have been focussed on catch quotas, and specifically on determining the value of the TAC and its allocation, has had two serious effects.

The first effect has been that within the North Atlantic fisheries (or at least in the north-east), the TACs have become ends in themselves. The general impression given by much of what is said about current problems of managing North Sea fisheries is that if only the correct TACs were agreed on, and complied with, then the fisheries would be properly managed. (This also appears, with a nationalistic flavour, in the belief that if all the foreigners would accept a proper, low share of a TAC, then all would be well.) In fact a catch quota is only a means to an end; unless further action is taken, the imposition of a catch quota goes only a little way towards reducing excess costs and realizing the large economic benefits pointed out by the ICNAF studies of nearly two decades ago. This is not the place to attempt an analysis of what is wrong with current management practices in the North-east Atlantic, still less to suggest prescriptions for improvement. However, it does seem that some shift in attention away from catch quotas could be useful.

The second effect has been more widespread. This is the belief that catch quotas are the only correct way to manage a fishery. Nothing in North Atlantic experience, or in the arguments put forward in favour of catch quotas for the North Atlantic cod fisheries of the 1960s, prove that they would be the most suitable way of controlling the amount of fishing in most present-day fisheries. One factor favouring catch quotas (that a large number of countries all had free access to the stocks) now only applies to tuna and a few other species that can be taken on the high seas. Another (that the stocks were of long-lived fish, without large and unpredictable changes in abundance from year to year) is not typical of most other resources, especially in warmer waters. This point is discussed further in the following section.

3. COMPLICATING FACTORS

The assumption that Figure 1 gives an adequate representation of real life and hence that, from the resource point of view, the choice of management measure is unimportant, can break down in various ways. This can lie within the model itself or can lie outside the model.

Within the model it is not necessarily true that fishing mortality, fishing effort and catch have a neat one-to-one relation. In different years the same catch or the same nominal fishing effort will give rise to different values of fishing mortality. If, as is common, the basic strategy of management involves maintaining a certain fishing mortality, this is undesirable and can be dangerous. Similarly, different catches or different levels of fishing effort (or fishing mortality) will be needed to maintain a certain spawning stock, depending on the current abundance. An annual catch quota must therefore be based on a reliable and up-to-date estimate of the abundance of the total stock, and as necessary of the spawning stock.

The assumptions of the economic aspects of the model, that the costs and value of the fishery are proportional to the fishing effort and the weight caught, respectively, are not always true. If they are not, then any changes in the pattern of fishing brought about by management will not have the economic effects predicted. To the extent that the departures from the assumptions are actually caused by the management action, the results can be very significant. This is particularly true when, as is usually the case, the effect of the regulations is either to increase the costs of a given level of fishing effort (or, more correctly, of exerting a given level of fishing mortality) or to reduce the value of a given catch. When managing an over-exploited fishery, with excess catching capacity, it is often easiest to achieve the immediate objective of reducing the fishing mortality by reducing the efficiency of the fleet (shorter open seasons, prohibition of certain types of gear, etc.). This will increase the costs of exerting the target mortality. Any disruption of the normal pattern of fishing will also tend to reduce the value of a tonne of fish, e.g. by concentrating all the landings in a short open season.

The simple model ignores many biological complications even within a unit stock. All fish in the stock are not the same. A catch of a ton of fish will have different effects on the stock and fetch a different value on the market depending on the size or condition of the fish. Very small fish may be worth so little that they are discarded at sea. Management measures may cause the sizes or conditions of fish caught to vary and may change the discarding practices of the fishermen.

No fish stocks exist in isolation, and many fisheries are concerned with only one stock. Biological interactions, e.g. between predators and prey (whales/krill, cod/herring, seals/capelin), have seldom been explicitly taken into account in setting management measures in the past. In the future, though, it is clear that they will have to be more carefully considered. This raises difficult biological problems, e.g. in designing suitable models and still more in fitting the models to data. They also raise difficult social and political problems, especially when marine mammals are concerned, in determining the most suitable management policy, e.g. in balancing the interests of those wishing to harvest krill against those wanting the most rapid rebuilding of whale stocks. These problems concern the strategy of management, e.g. determining the appropriate levels of fishing mortality for the various interacting species. They however do not affect the question at issue here, of the correct tactics and the measures for achieving, e.g. the target fishing mortality.

The tactical questions are the extent to which one or other choice of measure to manage one stock can affect the harvesting of other stocks. Preferably, the controls on an over-exploited stock should encourage the greater use of under-exploited stocks. The practical effect is however often the opposite. Restrictions on the type of the gear that can be used are particularly likely to inhibit the greater exploitation of under-used stocks. Difficult problems are also posed by the incidental catches of the "protected" species by vessels fishing for other species - should they be allowed to keep them and if so how many. A low limit can mean loss by discarding and a high limit a degree of fishing that is really directed at the target species.

As more management schemes are implemented, the incidental costs of different patterns of management and some of the unexpected effects, not covered by simple theoretical models, are becoming apparent. The most obvious costs are of the additional research, administrative and enforcement activities that are needed to determine the regulations for each year in the necessary detail and ensure they are actually followed. Enforcement, particularly when it requires close checking on the activities at sea, can be very expensive. These costs, and also the costs of research, can be greatly affected by the type of measure used.

The most serious indirect effect of regulation occurs when they lead to mis-reporting of basic data. Where catch quotas are in operation but not fully enforced, the actual landings may be considerably in excess of the figure reported. This has, in some cases, reached the stage where the scientists concerned have had to report that it is no longer possible for them to make meaningful assessments of the state of the stock.

The following sections will review the degree to which management by catch quotas can deal with these complications, as judged by the four criteria of maintaining the resource, economic efficiency, equity, and transaction costs. First, though, the actual mechanics of applying a catch limit will be examined.

4. THE MECHANICS OF CATCH LIMITS

The implementation of a limit on catches involves two or three inter-dependent stages - determination of the level of the total allowable catch (TAC), usually though not always the allocation of shares in the TAC to different groups of fishermen, and some control system to ensure that the catches of each group are no more than their allotted share.

Normally, the common practice is for the TAC to be set according to the scientific recommendations. These will be based on some interpretation of the basic management objective (to exert a fishing mortality equal to $F_{0.1}$, to maintain the stock at the level giving the MSY, etc.), together with the available information on the current stock abundance, etc. In practice the TAC is often modified from the scientific conclusions in order to resolve some immediate problem.

The preparation of the scientific recommendations, which for the ICES area has been described by Hoydal in a paper to this Consultation, meets two major obstacles. First, the value of the appropriate quota is not uniquely determined by the biological conditions but depends on the specific objectives (MSY, $F_{0.1}$, etc.). These may not be explicitly defined and the scientists will then have to make some assumptions. Second, the data on the current conditions of the stock will never be absolutely precise. Even if pre-recruit surveys are carried out, the strength of the youngest year-class in the stock in the coming season will rarely be accurately known. There will therefore always be some doubts and imprecisions in the estimated quota. Only rarely is there a good understanding between the scientists and the managers on how to deal with these uncertainties. If the scientists take the natural course and express their conclusions as a range - "to exert a fishing mortality equal to $F_{0.1}$, the quota in 1983 should be between 95,000 and 120,000 tons", then too often the administrators have taken the easy course, and used the upper limit (i.e. 120,000 tons). The response of the scientists has then often been to play down the uncertainties, and to give a single figure, usually towards the more conservative end of the range. In doing this they are tending to act as though the scientists had the ultimate responsibility for the resource. In the short run this is probably a good thing, with better levels of TAC being set. In the long run, however, it would seem more appropriate for the uncertainties in the scientific advice (which include doubts about the models being used, as well as the estimates of year-class strength, etc.) and in the models to be dealt with in the final decision-making process together with all the other uncertainties.

The allocation of the TAC between various groups is the key stage so far as economic efficiency and equity is concerned. Without some allocation, implementation of a catch quota involves an ever-shortening open season, during which there is an open competition between all the fishermen to get as much as they can while the season lasts. The chances of much economic benefit is small.

In international fisheries the importance of allocation to countries is well recognized. As noted in the first section this can be easily done only in terms of catch, which is why catch quotas have dominated the thinking about international fishery management.

Allocation is equally important within national fisheries, until the sub-division of the fishery is fine enough for there to be little competition within a group. How much division is needed will vary. Antarctic whaling was carried out by large expeditions, so that even at its peak each national quota had to be shared by at most two or three big companies. Near-shore fisheries, dominated by small family-owned boats, may require several layers of allocation - perhaps first by port, type of gear, or size of vessel, etc. and then sub-divisions within these categories.

Allocation within a country need not be expressed solely in terms of catch, even when the overall limit is so expressed. Limits, for example, on the total number of vessels that can be operated, or on the numbers operated by a particular company, will prevent much of the uncontrolled competition that dissipates the benefits of an un-allocated total catch quota. Such forms of allocation can avoid some of the problems that arise when all allocations are made in terms of catch. Then there can be a lack of distinction between allocation of a proportional share (in some unspecified total) and a share expressed as so many tons of fish. The latter runs into trouble if the stock should decline, e.g. due to poor recruitment; then the sum of the allocated shares may exceed what can be taken from the stock.

The problems of enforcement of catch quotas have, until recently, been neglected, at least in the published literature. When there was little detailed allocation, it might not unreasonably be assumed that catches were correctly reported. The problems were those of having a sufficiently quick administrative system, so that fishing could be stopped rapidly once the target catch was approached. Once each small group is allocated a share in the total, then there will be an incentive for the fishermen in that group to under-report their catches. This mis-reporting, which if extensive, can undermine the whole statistical system on which the assessment and management of the fishery is based, has apparently reached the stage in some areas where the scientists have to state that they can no longer make reliable assessments of the state of the stock.

5. EVALUATION

5.1 Effect on resources

In principle, given adequate knowledge of the abundance of the stock in the coming season, a catch quota enables the impact of the fishery to be maintained at the desired level, whatever that may be. In practice, knowledge of the resource is less than perfect and the catch quota set will not be the correct value to achieve the desired input on the stock. The extent to which its effect will be closer to the desired one than those obtained through other types of control (e.g. on effort) depends on the year-to-year variability of the stock, and the degree to which these can be measured and predicted. At one extreme, whales live a long time and the population varies little. Catch quotas are highly suitable for whales. Stocks of long-lived fish (halibut, cod in northern waters, etc.) live a long time and, though year-classes vary, it is possible to monitor these changes reasonably well in advance of their full impact on the commercial catches. For these too, control by catch is suitable, though probably no better than effort limits. For the more short-lived stocks, e.g. those in the North Sea, and especially in tropical areas, it is difficult to make accurate estimates of the abundance in the following season. A significant part of the catch comes from the newly recruited year-class which can only be estimated by pre-recruit surveys. These tend to have both high costs and high variance. For these stocks other types of control, e.g. on effort, may provide better control of the resource. Exceptions are some of the shoaling pelagic species. Because for these the catchability coefficient varies inversely with abundance, limits on the nominal fishing effort gives little control of the actual fishing mortality. On the other hand, it may be possible to use acoustic surveys at the beginning of the season to get a direct estimate of the current abundance, and thus use catch limits successfully.

Catch limits are useful only if enforced. This point is discussed further in Section 5.4. Enforcement is however almost inevitably of landings, not catches. Some forms of "catch" control can lead to increased discards. The landing of "regulated" species (e.g. Pacific halibut) by fisheries directed to other species may be prohibited. Alternatively a certain percentage of by-catch may be permitted. This can lead to deliberate fishing for the "regulated" species early in a trip to make sure of the allowed percentage, followed by the discarding of any further catch. To the extent that such discards are poorly recorded and not taken account of in the statistical data, the impact on the resource is greater than expected.

5.2 Economic efficiency

This depends on the extent to which the total catch is allocated to individual groups. At one extreme, with a single global quota, management leads to a scramble for the quota, a short season, and great economic inefficiency (excess capital employed, high catching costs, and often reduced value of the catch). At the other extreme, when each individual enterprise is allocated its own share, economic efficiency is high. If a fisherman knows that he can take say, 100 tons at some time during the year, he can arrange to take this at the most profitable time taking account of seasonal variations in fish conditions and market demand, the costs of catching, and the opportunities to engage in other fisheries.

Compared with control of effort, catch limits - provided that there is some allocation - have the economic advantage that they do not lead to distortion of fishing practices as fishermen try to out-manoeuvre the manager, e.g. by building larger boats, or more powerful boats within a tonnage limit. These distortions must inevitably lead to some degree of inefficiency.

5.3 Equity

This too depends on the nature of the allocation rather than catch limitation per se. Without allocation, not only will much of the economic benefits be dissipated, but such benefits as are gained will go to those who can maximize their share of the catch. These will be those fortunately located with respect to fishing at the beginning of the season, or who can best build up their catching capacity. These will seldom be those who the managers would actually wish to give particular preference to.

When there is allocation, the pattern of allocation can obviously be arranged so as to favour any desired group. With detailed allocation the social impact of control by catch is likely to be similar to that of control by effort. Similar problems will be raised - who should get licences/quotas, for how much, can they be transferred. An apparent advantage of catch limits is that they are clearly comparable - a man with a quota for 100 tons has twice the "benefit" of someone with 50 tons. This is certainly an advantage in multi-national fisheries. It may be more apparent than real at the national level, where the question is whether or not an individual can continue to run his boat, or whether a company has to reduce its fleet, and by how much.

5.4 Transaction costs

The year-to-year adjustments in catch limits, which are essential in all but the least variable of fisheries, are costly. At the least, they involve research staff in time-consuming re-calculations, often under severe pressure of time (dealing with this year's data in order to set next year's catches). The costs in terms of diversion of scarce scientific man-power from other tasks, including the adequate consideration of the broader aspects of resource assessment and management advice, may be large. Often there will also be considerable financial costs to carry out, for example, pre-recruit surveys. These scientific costs are likely to be more than those involved in other forms of control.

In contrast, to the extent that controls on the amount landed (but not the amount caught) can be checked in part, costs of enforcing catch regulations are at least no higher than those of enforcing other measures. However, if several stocks of the same species are being managed independently, and the fish from different stocks cannot be distinguished on the market, then control must be carried out at sea. Also, particularly for high-priced species (lobster, salmon, sole, etc.) it is possible for much of the catch to be sold without passing through recognized markets (or to pass through those markets identified as something else). Control of catch limits may therefore not be as easy as might be

supposed from a superficial examination, and may well involve costly control at sea. In addition, it may be less obvious to other fishermen that catch limits are being observed than limits of other kinds - it will be fairly clear what vessels (and of what size and type) are fishing in an area, but less clear how much they are catching. It may be harder in the case of catch limits than for effort limits to build up a mutual trust between fishermen that the regulations are being observed by all those in the fishery, although this trust may be the key to reliable implementation of management measures. Finally, it should again be noted that poorly enforced catch quotas can undermine the supply of reliable catch statistics, which is the basis of the scientific side of fishery management.

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NOTES ON THE SCIENTIFIC PROBLEMS OF TAC MANAGEMENT

by

J.G. Pope
M.A.F.F. Fisheries Laboratory
Lowestoft

1. INTRODUCTION

Limiting fishing mortality by catch quotas (total allowable catches or TACs) requires the input of scientific advice if it is to be successful. In some regions, aspects of this advice are fairly routine, while other aspects are in clear need of development. In other regions, almost everything remains to be developed if this method of managing fisheries is to be adopted. This paper seeks to review briefly the scientific methods used and their limitations. It seeks to indicate where new technique is needed and where more dialogue is required between scientists, administrators and fishermen.

2. OBJECTIVES OF MANAGMENT

2.1 True objectives and proximate goals

The management of fisheries may be aimed at a number of possible objectives. For example, it might seek to maximize the catch of the fishery, to maximize the employment of fishermen and ancilliary workers, to maximize the economic yield either to vessel owners, fishermen or government. Again it might seek to maximize foreign earnings or ensure a regular supply to consumers. There thus tend to be a bewildering complexity of possible objectives, many of which are conflicting and few of which are properly quantified. For these reasons the aims of management are often expressed as the attainment of some proximate goal such as (a) to maintain the current level of fishing mortality or some proportion of it, and (b) to attain some specified level of fishing mortality such as F_{max} which gives the maximum sustainable yield or $F_{0.1}$ which approximates to the maximum economic yield.

Clearly these proximate goals are aimed towards the yield-maximization or profit-maximization objectives of fisheries management but the extent that they will meet this latter objective or indeed any other objective is not very clear. A detailed study of the relationship of the proximate goals to the objectives of management would be very useful. Has it been made anywhere?

I would expect that the proximate goals would prove valuable as a way of approaching some objectives, counter-productive for other objectives and irrelevant to some other objectives. Given the proximate goals, however, catch quotas are an obvious means of obtaining them.

2.2 Problems with the definition of proximate goals of fisheries management

Although the proximate aims of fisheries management give the impression of crispness, there are in fact several points in the definition that need clearing up. How accurately do they need to be attained? Would a systematic bias of 10 percent either way worry anyone? Would they need to be precise each year or would it be sufficient if the goal was met on average? Do we need to specify a maximum variability? Where the link between fishing effort and fishing mortality is fixed the answer is probably that the variability of the goal might well have important economic costs. Both Rivard (1981) and Pope (1981) consider that TAC management should have a 10-percent coefficient of variation, if this is achievable. Where the link is variable, as it often is for pelagic species, very precise TACs may be inappropriate. Certainly then there is a need for discussion on how accurately and precisely proximate goals need to be set, between the scientists who have to estimate TACs, the administrators who apportion them and the fishermen who suffer their consequencies. The answer to scientific problems, such as how precise various data sets really need to be, will ultimately come from the answer to this question. So will the answer to the question of what stocks might reasonably be managed by TAC.

Another problem with the proximate aims is just what is meant by fishing mortality. Fishing mortality (the instantaneous coefficient of fishing mortality) occurs as a potentially-independent variable on each separate age of fish. Clearly some overall measure of fishing mortality is required and the quick answer is usually that the mortality referred to is the fully-recruited mortality. What however is this?

The text table shows several different sets of fishing mortality at age:

Fishing Mortality at Age

	A G E							
Set	1	2	3	4	5	6	7	8
I	0	.4	.8	.8	.8	.8	.8	.8
II	.4	.8	.8	.8	.8	.8	.8	.8
III	.8	.8	.8	.8	.8	.8	.8	.8

For sets I, II and III, the fully-recruited fishing mortality is 0.8 but obviously set III has more mortality than set II, which in turn has more than set I. If these results came from three successive years then we would hardly be justified in assuming that the mortality had remained the same. The goal that the mortality should stay the same as last year's thus should perhaps be that the fully-recruited mortality should remain the same and the exploitation pattern (the proportions in which this is distributed over the various ages) should also remain unchanged. The problem is that the exploitation pattern can be observed to vary considerably from year to year. The problem then is to express the result of all mortalities as a single figure. Shepherd (1982) gives two estimators of overall fishing mortality which go some way towards this need. Both are weighted means of fishing mortality at age. The first (F_c) is weighted by the catch number at age that would result from a single cohort of fish with these mortalities at age. Under this measure, run II would show the same result as run I. In other words, it might be thought of as being generated with the same level of fishing effort but with a smaller mesh size. It would thus be a useful measure where a mesh change was applied. The second means (F_p) is weighted by the population number at age. It would thus indicate that mortality was higher for set II than set I. It would be useful as a general measure of biomass erosion.

Another approach is simply to assume a constant exploitation pattern and to impose this on the interpretation of fishing mortality. This is the approach adopted in many least-squared interpretations of catch at age data. For example, that of Pope and Shepherd (1982) expresses fishing mortality on age j in year i as $F_i \times S_j$, where F_i is an annual fishing mortality and S_j the exploitation pattern. Such an interpretation does therefore give a single estimation of mortality for each year. In some senses this is justified because fisheries scientists need the concept of a fixed exploitation pattern in order both to estimate F_{max} levels and to forecast catch levels (e.g. to estimate TACs). Thus there may be some justification in finding what is in a sense the best average exploitation pattern and using it. In another sense, however, it is only reasonable if departures from this separability model are random since systematic departures (e.g. a trend with time) will cause bias. Clearly the fishing mortalities on the several ages of fish cannot always be adequately described by a single dimensional vector. For example, a principal component analysis carried out on the North Sea haddock from 1961 to 1976 indicated that there were in fact two almost orthogonal components where fishing mortality at age was considered as variables and years as cases. These indicated that the mortality on younger ages formed one component (corresponding to by-catches in the industrial fishery), while the mortality on the older ages formed another component. These two components appeared to account for most of the coherent variation (63 percent) of fishing mortality at age in these years and properly, therefore, we should have to talk of the fishing mortality on haddock in terms of the level of each of these two components. At Lowestoft we are currently developing a two-fleet version of the Pope and Shepherd (1982) method which should enable this to be carried out in a systematic fashion. Given such interpretations, the proximate goal of management might be to maintain the mortality on both components at their current levels, or perhaps to increase one by 10 percent and decrease one by 10 percent. This would, of course, mean setting separate TACs for separate fleet segments. It underlines what is an often neglected problem: that the proper level of a TAC depends to some extent on its allocation to different fleets or gear types or countries.

2.3 Timing of Advice

The advice fisheries scientists can give on future fish catches and hence TACs is very much a function of how far ahead the advice has to be given. The shorter the time between the advice being given and being used, the more precise and accurate it is likely to be. As the time extends, changes in the recruitment levels of new year classes of fish, unknown catch levels in intermediate years and changes in exploitation pattern all add sources of error to the prediction. Thus in principle administrators need to think of ways of shortening the time between advice being given and being used. This may perhaps be achieved by TACs being set provisionally and then being adjusted, if this is necessary, nearer to the time of application in the light of fresh evidence. This problem of timing is a very serious problem for fisheries scientists which administrators should perhaps be more aware of.

3. ESTIMATION OF TACs

The estimation of appropriate TACs is usually undertaken by fisheries scientists. The methods used for estimation vary according to the particular problems associated with the fishery and with the availability of data.

3.1 Variability of TACs

Scientific advice for fisheries management by TAC is often given so as to satisfy one of the proximate goals. If these goals are to be satisfied accurately then detailed knowledge of the biomass of fish by age or size is needed. Since variation in recruitment to the fishery causes this to vary with time, it also follows that TACs will generally need to be re-assessed with time, often on an annual basis. The effect of variation in recruitment on TACs is important to understand because it may determine the types of situation for which TAC management is applicable.

Fish catches are often composed of a number of ages of fish. Indeed where this is not the case, the prediction of a future catch (such as a TAC) may be very problematic. The yield in year t - Y(t) - may be written simply in terms of the numbers of fish recruiting each year R(i), the weight of age j - W(j), the exploitation proportion Ex (t,j) for each age j in the current year t and the proportion of the recruitment surviving from year i to year t - SU(t,i).

Thus,

$$Y(t) = \sum_{j=o}^{j=g} R(t-j)\ W(j)\ Su(t,i)\ Ex(t,j) \qquad (1)$$

where, g is the oldest exploited age.

Clearly changes in any of these factors from year to year can change the catch. In practice all do change to some extent from year to year. Table 1 shows the range of variation of recruitment for some North Sea fish stocks over a number of years. In higher latitudes this often proves the greatest source of variation in yield. This may of course not be the case for fisheries in other climatic regions. For example, the rather systematic declines of biomass seen in the groundfish-survey results from the Gulf of Thailand; Pope (1979) suggests that there the recruitment variation may be less, although systematic changes are quite possible. Since the objective of the TAC management is often to stabilze levels of fishing mortality and hence the Su(t,i) and Ex(t,j) terms in equation (1), we may conveniently regard yields as weighted sums of recruitment data. The weighting factor is of course:

$$W(j)\ Su(t,i)\ Ex(t,j)$$

Following equation 6.31 of Beverton and Holt (1957) we may express this simply as:

$$\sigma_y^2 = \sigma_r^2 \sum_{j=1}^{g} \left(W(j)\ Su(t,i)\ Ex(t,j) \right)^2 \qquad (2)$$

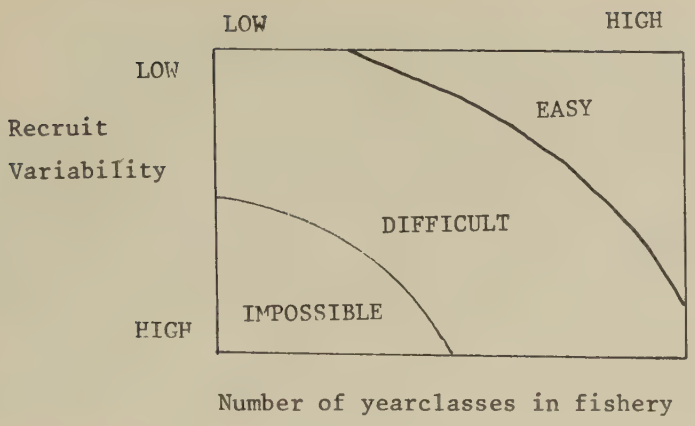
where, σ_y^2 and σ_r^2 are the variances of yield and recruitment, respectively.

Table 1

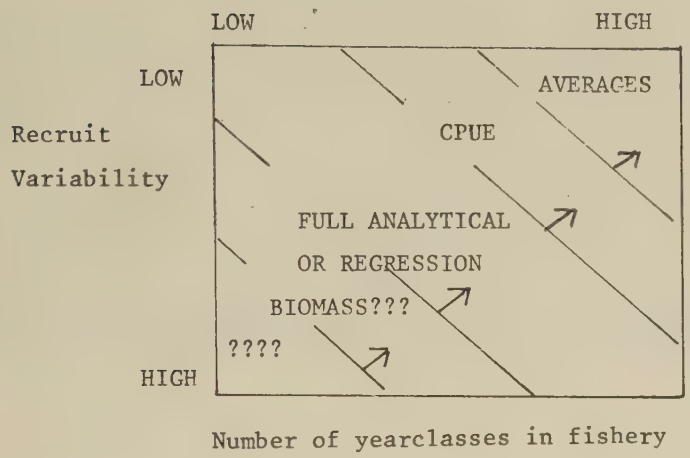
Recruitment variations in North Sea fisheries, 1963-1978
Number adjusted to a value of 100 for the most outstanding year-class of each species
Ratio is the ratio between the numbers in the strongest
and weakest year-classes in the period

Year	Cod	Haddock	Whiting	Saithe	Plaice	Sole	Sprat
1963	50	6	30	21	100	100	
1964	47	11	43	28	29	21	
1965	67	8	30	22	28	11	
1966	60	31	38	62	26	11	
1967	20	100	100	64	22	18	
1968	18	21	18	69	28	9	
1969	78	3	44	35	33	26	
1970	100	47	54	34	26	7	
1971	17	24	68	36	22	16	
1972	35	5	73	41	57	20	
1973	29	36	48	100	49	19	59
1974	50	4	68	34	34	7	81
1975	24	6	35	25	27	20	35
1976	88	12	42	14	54	23	51
1977	37	18	46	29	46	7	100
1978	34	24	45	42	34	0.2	32
Ratio	6	33	6	7	5	500	3

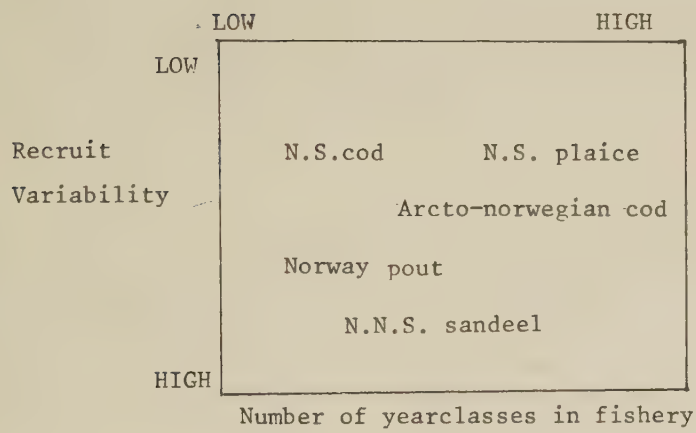
Fairly clearly with slow growing, low mortality stocks, the yield will come from fish from a number of ages and will thus tend to average out some of the variation in recruitment. On the other hand, fast growing, high mortality stocks will have yields which more nearly vary as recruitment. Thus yields will tend to vary least from year to year on low mortality stocks and on stocks with low variation in recruitment. For such stocks of fish, simple approaches to estimating TACs may be adequate. It may also be possible to make predictions for a number of years. The main safeguards required will be checks that mortality or recruitment levels are not systematically changing. For stocks with a high variation in recruitment and with a small number of ages contributing to the catch, more elaborate methods will be required and predictions will only be reliable for short-time periods. In some cases the shortness of this period may preclude estimating a TAC in sufficient time to be useful. For example, northern North Sea sandeel yields sometimes depends heavily on catches of "0" group fish (in 1979, 61 percent of the total yield) which could only be estimated a few weeks before fishing started. It would therefore be very difficult for scientists to meet to agree on a TAC and administrators to meet to allocate it in this time frame. In general the time lag between data being collected and TACs being set is one year. For example, data are collected in 1982 to be assessed (scientific advice prepared) in 1983 to set the 1984 TAC. Where this is the case, the prospects are not good for setting reasonable TACs on fish stocks with high mortalities and variable recruitments. For such stocks either mortality rates have to be first reduced (if they are man generated) or other methods of management found. Figure 1 shows a schematic picture of this problem. The simplicity or difficulty or impossibility of setting TACs which are precise and accurate is seen as a function of recruitment variability and of the number of ages of fish present in the fishery.



1a) Difficulty of setting TACs



1b) Possible methods



1c) Rough position of some stocks

Figure 1

The difficulty of setting TACs, the methods applicable and some typical fish stocks related to the variability of recruitment and the number of important year-classes in the fishery

3.2 Estimation method for TACs

Simple approaches :

The simplest approach to TAC estimation is to take a straightforward average of the total catch in the past n years, say over the past five years. Clearly this approach will only be satisfactory if fishing mortality has been stable and if the stock is little affected by recruitment variation, either because variation in recruitment is low or it is averaged over a number of years. While this method is obviously crude, it does reflect the immediate past behaviour of the system. It is possible that some weighted mean of the past five years' data might be a rather better approach since this could give more weight to the most recent years' result. For example, weights of 1/15, 2/15, 3/15, 4/15 and 5/15 might be used to weigh the yields in years t-5, t-4, t-3, t-2, t-1, respectively. Whichever of these methods were used, it would be wise to improve the data available on fishing intensity and recruitment, so that methods which do not rely on the stationarity of recruitment and fishing mortality could be adopted at a later date.

Methods based on catch-per-unit of effort data and effort data :

Where effort and catch-per-unit of effort data are available, predictions of the catch can be made assuming the catch-per-unit of effort in the next year will remain similar to that in the current year. Thus if it is intended to change the fishing mortality (e.g. to F_{max}) then the new yield can be predicted as the old level of catch-per-unit of effort times the new effort. This approach was used by ICNAF to set TACs for some species assessed by using production curves (e.g. red fish - McKone, 1978). The method might be a little more elaborated using the approximation given by Walter (1975). This relates catch-per-unit-effort in year i to the fishing effort in year i-1 and thus might be used to improve the estimation of catch-per-unit-effort used to predict the TAC.

Either method could be used with commercial catch-per-unit-effort data or with relative biomass estimates from an annually repeated ground fish survey or an annually repeated acoustic survey. This use of acoustic surveys would not necessarily require an accurate estimte of fish target strength in order for it to be used.

If annual ground-fish survey results are available then it might be possible to use the length distribution of fish caught in the survey to split the catch rate into two or more components, for example, an exploited phase component and a recruiting component. These might be used to form a regression of yield on the two catch rates. A somewhat similar procedure was adopted by the ICES Industrial Fish working group who predicted the 1982 catch of Norway pout from a regression of yield on estimates of one and two-year old fish caught in the international young fish survey which is conducted each year in the North Sea. A somewhat similar approach was proposed for the Arcto-Norwegian cod. Such a method of course supposes that fishing intensity has been stable in the past. In principal mortality rates or estimates of fishing effort might be included in such methods to allow for their changes.

Methods based upon the use of absolute estimates of biomass :

Absolute estimates of biomass could be used to estimate TACs. Obvious sources of such data are acoustic surveys and egg surveys. Results of acoustic surveys of fish stocks can sometimes be made with reasonable accuracy and precision. These might be used directly to estimate the exploitable biomass of the fish stocks and the TAC could then be set at some appropriate proportion of this. One problem with this approach is that the exploitable rather than the total biomass of fish is required. In other words the estimate would have to exclude the biomass of small pre-recruit fish. For species which shoal by size, however, this might be quite possible.

A similar use can be made of egg surveys. First, by using the estimate of total egg production and the fecundity per gram of mature females, to estimate the biomass of mature females and then, using the ratio of catch weight of mature females to all the landings, to gross up the mature female biomass to the total exploitable biomass. Thus again the TAC could be set to give some appropriate proportion of this biomass.

A problem with such TACs would be that they would be estimated on the current biomass and hence could only be used as forward projections if the biomass was unlikely to change, due to low recruitment variability or low mortality rates.

Full Analytical Methods :

In areas such as the North Sea, TACs are set by attempting to estimate the actual numbers at age in the most recent year possible. This is achieved by using VPA or cohort analysis or separable VPA to interpret the catch numbers at age data from past years. This gives estimates of fishing mortality at age and population number at age. These are used to calibrate past estimates of fishing-effort data as fishing mortality and past estimates of recruitment given by research vessel surveys as numbers at age. Current estimates of these factors can then be calibrated to give the current state of the stock including the number of pre-recruit fish. This information can then be used as the basis of a forecast which gives the TAC. This method will be treated in more detail in a paper by Hoydal and is explained in Layman's terms in Pope (1982).

In recent years considerable attention has been given to means of tuning the VPA (e.g. calibrating fishing effort data to give mortality and hence population in the last year). Such methods as the Gamma method, partial exploited biomass method, Saville's method, the Hoydal-Jones method, the Rho (son of Gamma) method (Anon, 1981; Saville, 1981; Laurec and Shepherd, 1982; Armstrong, 1982) are all attempts to make better use of effort data in this context. A preliminary comparison of these methods by an internal working group at the Lowestoft Laboratory (Variations and Fugues for the well-tempered cohort analysis) suggests that most of these methods are reasonable and that discrepancies between them may result more from the effort data used in specific circumstances than the method of calibration adopted. An important scientific problem can therefore be identified which is the need for a method for filtering out bad effort series.

The advantage of the full analytical model is that it attempts to account for all sources of variation in yield. Its disadvantage is that its complex structure might be vulnerable to errors in reporting total catches or discards. It is also vulnerable to poor estimates of catch-at-age data, recruitment or effort data. A potential disadvantage is that it uses data sets which may prove expensive to collect and not be possible for all species. For example, reliable effort data may prove difficult to acquire for shoaling pelagic fish, while age data may not be possible in the tropics. Another problem is that the analytical approach needs a number of years of data before it can be used (perhaps five or more years).

Some recent developments :

Pope (1983) suggests some simplifications to the analytical method for estimating TACs where the proximate goal is for fishing mortality to remain unchanged from the most recent year's level (such TACs may be called status quo TACs). The first of these methods called the leapfrog method can be used with only two years' data and might be of utility when data collecting has only recently been introduced.

$$C(t+1,j+1) = \frac{C(t,j+1)\,C(t,j)}{C(t-1,j)} \left(\frac{F(t-1)}{F(t)}\right)^2$$

and,

$$C(t+1,1) = C(t,1)\,\frac{R(t+1)}{R(t)} \left(\frac{F(t-1)}{F(t)}\right)$$

to give catch at age in the TAC year such that $F(t+1) = F(t-1)$. Since fishing mortality estimates appear as ratios, they may be replaced by fishing effort estimates providing these are directly proportional.

The virtue of the method is that it could be used while data for the full analytical method were being accumulated. The main problem is that the equations are likely to be very vulnerable to errors in fishing-effort data because of the use of ratios of effort.

The second of Pope's (1983) method uses the same data set as the full analytical model (i.e. catch at age data for a number of years, fishing effort data and recruitment data). The basis of the method is to interpret the matrix of log-catch ratios - i.e. in $\left(C(i+1, j+1)/C(i,j) \right)$ - as a two-way analysis of variance (ANOVA). Pope and Shepherd (1982) show this to be an appropriate structure for this matrix. Year effects are then correlated with a formulation of effort data and this is used to extend the log catch ratio matrix by two years (maintaining the year effects and overall mean unchanged). These extended years' log-catch ratios are then used to relate catch at age in the last year for which data are available to the catch at age in the TAC year. An advantage of this method is that no knowledge

is required of the level of natural mortality or fishing mortality (indeed these seem somewhat redundant parameters for the purpose of setting a status quo TAC). The method is perhaps most important in showing that setting a status quo TAC is essentially the problem of estimating transfer relationships between catch at age in the last year for which data are available and catch in the TAC year.

Another interesting recent method is the survivors method of Doubleday (1981). This uses what is in effect an exact form of the approximate cohort formulae of Pope (1972). This links population number at the beginning of the year with survivors at the end of the year and catch numbers during the year. This recurrence relationship is: Population = CINT + SINT, where CINT and SINT are an integral of catch and an integral of survivors, both adjusted for accumulated natural mortality. This relationship is then used to generate estimates of population numbers in past years and these are used to calibrate population estimates made from groundfish surveys, using a maximum likelihood procedure. Calibrated population estimates could then of course be projected to give TACs as with the full analytical model. The method could be useful in not using fishing effort data.

Two other methods for calibrating groundfish survey data are shown in Collie and Sissenwine (1982). One method is for when groundfish survey catch at age data and commercial catch at age data are available and the other is for when groundfish survey catch at age data are available but only yield data are available from the commercial catch. Both methods assume a constant catchability coefficient for the research vessel survey data. The method where only total yield data are available from the commercial catch would seem particularly useful because this is a situation where other analytical methods could not be used.

Nielsen (1982) shows a maximum likelihood estimation of fishing mortality based on the separability of mortality into year and age effects. In principle this seems - as did the methods of Doubleday (1976) and Pope (1977) - capable of estimating fishing mortality in the last year using only commercial catch at age data. In practice, however, this is estimated with low precision and thus rather confirms the result of Pope and Shepherd (1982) that there can be little information in the data about mortality in the last year.

New methods that need to be developed :

Analytical methods of TAC estimation still contain a number of scientific problems. Some methods which urgently need development are:

(a) An equivalent to Pope's ANOVA method based on a two or more fleet separable model.

(b) A simpler version of the analytical model based on length data rather than age data. This would be desirable for developing countries where the full analytical model may require more data (particularly age data) than is generally available and for minor or difficult stocks in developed regions.

4. ERRORS IN SOME METHODS OF ESTIMATING TACs

An obvious scientific problem concerned with estimating TACs is how accurate and how precise are the various methods. With regard to accuracy the simple methods make the assumption that the behaviours of fishing mortality and recruitment are simply random and have no trend with time. If either do have a trend with time, the methods will cease to be accurate. For example, if recruitment is collapsing then five-year running means of past catch data will obviously give TACs which are too high. Other methods are obviously susceptible to biases in the data sets used. For example, under reporting of catches, learning processes in fishing effort and trends in fishing power will all potentially upset analytical methods.

The problem of the precision of these various methods is quite difficult. It may be approached in several ways. For example, past predictions may in some cases be compared with the real results as in Macer et al. (1979). It is possible with some methods to see how well they would have worked in past years. For North Sea cod, Table 2 shows the predictions that might have resulted using a five-year running means and contrasting these with the catches that would have occurred had fishing mortality indeed been stabilized at the level of the previous year (adjusted yield). The results suggest a

coefficient of variation of about 31 percent. In other words, in some years the results may be out by more than 50 percent. The weighted mean method explained in Section 3 gave much the same result with a coefficient of variation of 28 percent and, in fact, none of these results would seem to improve on setting the TAC equal to the long-term average of the catch.

Table 2

Some possible predictors of catch for North Sea cod and their errors

Year	Adjusted yields	5-year running means	Errors	5-year Weighted means	Errors	Y(t-1)	Errors
68	180	174	6	198	-18	245	-65
69	168	207	-39	233	-65	279	-111
70	318	223	95	299	19	196	122
71	318	234	84	232	86	230	88
72	256	256	0	263	-7	328	-72
73	299	277	22	295	4	350	-51
74	193	268	-75	281	-88	236	-43
75	189	269	-80	260	-71	203	-14
76	198	262	-64	234	-36	191	7
77	209	238	-29	217	-8	212	-3
78	267	208	-59	204	63	198	69
79	247	219	28	231	16	289	-42
80	430	238	192	257	173	299	131
Average	252		6.2		5.2		1.23
	75		79		71		78
Coefficient of Variation	30%		31%		28%		31%

If the objective of management was to maintain the status quo, then a catch-per-unit-effort adjustment method would simply use the last year's catch to predict this year's catch - using the Walter (1975) approximation would cause some changes - since CPUE and effort would both be the same in the last year and in the predicted year. The results of using Y(t-1) to predict the adjusted catch are shown in Table 2. The coefficient of variation again is about 31 percent.

When acoustic estimates of biomass are used, the precision of the estimated TAC will be equivalent to the estimated precision of the acoustic biomass. Typically the accuracy of acoustic results are quoted in decibels. Often about $\pm$ 2 dB's, i.e. about $\pm$ 50 percent. Some results, however, have been reported better than this. Jakobsen (1982) shows results that appear to have a coefficient of variation of about 10 percent. To achieve this seems to require an isolated stock heavily concentrated in a known area such as the Icelandic summer spawning herring.

The precision of the 1977 egg survey carried out on the mackerel stock of the south-west of the British Isles gave results which probably had 95 percent confidence regions between +30 percent and -20 percent of the estimate of egg numbers (Lockwood et al., 1981). The estimate for exploitable biomass would presumably be rather less precise than this, since it would contain additional errors from the fecundity estimate and the mature female proportion in the estimate.

Regression methods of course lend themselves to the estimation of precision. The Norway pout estimates had coefficients of variation of between 15 percent and 25 percent. Using a similar approach for North Sea cod, the results could have a coefficient of variation of about 20 percent, using the international young fish survey results. Not surprisingly a better fit is obtained with the actual numbers at age given by VPA, which could give a result with a coefficient of variation of 10 percent. Whether this discrepancy is due to errors in the total yield estimates and hence catch at age data, or due to changes in the young fish survey, is not clear. In principle a regression approach could be a valuable step between simple methods and the full analytical model.

The precision of the full analytical model is a much more complex question than that of the other methods. Unfortunately, answering this question fully is not easy because the standard practice is both recursive and somewhat subjective. It usually entails the following steps:

(a) Establish data base and update each year

(b) Use VPA or equivalent to interpret past years' catch at age data, subject to assumptions about terminal fishing mortality

(c) Make minor changes to terminal values to obtain consistent interpretation

(d) Calibrate fishing effort data

(e) Use calibrated effort to estimate terminal fishing mortality

(f) Repeat steps (b) and (e) until terminal values are unchanged

(g) Calibrate recruitment indices

(h) Use results from steps above to forecast TACs usually two years ahead

Clearly this calculation route is complex and it is difficult to see how to investigate the variance of the resulting TAC. Several attempts have, however, been made. The problem can be eased by considering only the variability generated in step (h) above. This approach was used by Pope and Garrod (1975) and in a sensitivity analysis shown by Doubleday (1979).

Another alternative is simply to consider how well past TACs have been set (e.g. Macer et al., 1979; Lassen, 1980). Yet another is to set independent working groups to assess the same data as in Garrod, Pope and Knights (1977). This latter approach, of course, only shows the different interpretations that could be put on the same data rather than the true variability. As a short cut, a Monte Carlo simulation approach has much to commend it. Pope and Gray (1983) have adopted such an approach and their results for North Sea plaice, North Sea cod and North Sea sprat are shown in Tables 3 to 11. For each of these three stocks, a simulacrum was constructed which corresponded as closely as possible to the working groups' interpretation, but which had fishing mortality which was separable into year and age effects. This was used to generate exact data sets which were then subjected to different levels of pertubation by random numbers to simulate the inprecise data met with in the real world. A series of TACs were then generated at each error level for each data set to give a 4 x 4 x 4 factorial design. TACs were calculated to meet three possible proximate goals. These were, where F(t) is the fishing mortality in the last year for which data are available and year t+2 the TAC year:

$$F(t+2) = F(t)$$

$$F(t+2) = F_{max}$$

$$F(t+2) = 0.5$$

In all cases $F(t+1) = F(t)$.

In practice additional important sources of variation arise from weight at age data (Rivard, 1981) and uncertainty about fishing mortality in year T+1. What is particularly interesting about the results is that variability seems to be far less when $F(t+2) = F(t)$ than the results for other proximate goals. This is a result of some internal compensations in the method when this proximate goal is chosen. It is also least subject to effort generated errors, which is fortunate since this is less capable of change than the other error sources. Thus, fairly clearly, the precision of TACs is a function of the amount of sampling input to the stock and also of the choice of proximate goal. There are this problems here for both scientists and administrators to solve.

Table 3

Coefficients of variation of 1982 North Sea plaice TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = F(1980)

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	3	6	12
	10	5	6	8	13
	20	10	11	12	16
	40	22	23	24	26
15	0	8	9	11	15
	10	10	11	12*	16
	20	14	14	16	19
	40	26	26	27	29
30	0	17	17	18	21
	10	18	18	19	22
	20	21	22	22	25
	40	32	33	34	37
60	0	29	29	30	32
	10	29	29	30	32
	20	31	31	31	34
	40	37	37	38	39

* Highlighted cell is authors' personal estimate of current situation

Table 4

Coefficients of variation of 1982 North Sea plaice TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = F_{max}

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	3	6	12
	10	8	9	10	15
	20	14	15	16	19
	40	30	31	31	34
15	0	23	23	24	26
	10	25	26	27*	29
	20	30	30	31	33
	40	45	46	47	49
30	0	48	49	49	51
	10	52	53	53	56
	20	57	58	58	61
	40	80	80	81	84
60	0	112	112	113	115
	10	115	115	116	118
	20	122	122	123	124
	40	136	136	137	138

* Highlighted cell is authors' personal estimate of current situation

Table 5

Coefficients of variation of 1982 North Sea plaice TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = 0.5

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	3	6	12
	10	7	7	9	14
	20	13	14	15	18
	40	28	29	30	32
15	0	23	23	24	27
	10	24	25	25*	28
	20	28	29	29	32
	40	43	44	44	47
30	0	48	48	49	51
	10	50	50	51	53
	20	56	56	57	59
	40	77	77	78	80
60	0	112	112	113	114
	10	113	113	114	115
	20	119	119	120	122
	40	132	132	133	135

* Highlighted cell is authors' personal estimate of current situation

Table 6

Coefficients of variation of 1982 North Sea cod TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = F(1980)

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	12	23	43
	10	2	12	23	44
	20	5	13	24	44
	40	10	15	25	45
15	0	13	17	26	45
	10	13	18	27*	45
	20	14	18	27	46
	40	17	21	29	47
30	0	23	26	32	48
	10	24	26	33	48
	20	24	27	33	49
	40	27	30	35	50
60	0	34	36	37	49
	10	35	36	39	49
	20	36	37	40	50
	40	40	39	44	53

* Highlighted cell is authors' personal estimate of current situation

Table 7

Coefficients of variation of 1982 North Sea cod TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = F_{max}

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	12	24	44
	10	5	13	24	44
	20	9	15	25	45
	40	13	18	27	47
15	0	22	25	33	51
	10	22	26	33*	51
	20	24	27	34	52
	40	27	29	36	54
30	0	43	45	50	65
	10	43	45	50	65
	20	44	46	51	66
	40	48	50	55	69
60	0	84	85	87	96
	10	85	85	88	97
	20	87	87	90	99
	40	95	96	98	107

* Highlighted cell is authors' personal estimate of current situation

Table 8

Coefficients of variation of 1982 North Sea cod TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = 0.5

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	12	23	44
	10	4	13	24	44
	20	9	15	25	45
	40	17	21	29	47
15	0	22	25	33	51
	10	22	26	33*	51
	20	24	27	34	51
	40	29	31	37	54
30	0	43	45	50	65
	10	43	45	50	65
	20	44	46	51	66
	40	49	51	55	69
60	0	84	85	88	96
	10	85	86	88	97
	20	87	88	90	99
	40	95	96	99	107

* Highlighted cell is authors' personal estimate of current situation

Table 9

Coefficients of variation of 1982 North Sea sprat TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = F(1980)

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	9	19	40
	10	2	9	19	40
	20	4	10	19	40
	40	9	12	20	41
15	0	1	9	19	40
	10	3	9	19	40
	20	5	10	19	40
	40	9	12	20	40
30	0	5	10	19	39
	10	5	10	19	39
	20	7	11	19	39*
	40	11	14	21	40
60	0	15	18	24	40
	10	16	18	24	40
	20	17	19	25	40
	40	20	22	27	42

* Highlighted cell is authors' personal estimate of current situation

Table 10

Coefficients of variation of 1982 North Sea sprat TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = F_{max}

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	9	20	42
	10	3	10	20	42
	20	6	11	20	42
	40	12	15	22	43
15	0	11	14	22	43
	10	11	14	22	43
	20	12	15	23	43
	40	16	18	25	44
30	0	26	28	33	50
	10	26	28	33	50
	20	27	29	34	50*
	40	29	31	35	51
60	0	87	88	91	100
	10	87	88	91	100
	20	88	89	92	101
	40	90	92	95	103

* Highlighted cell is authors' personal estimate of current situation

Table 11

Coefficients of variation of 1982 North Sea sprat TAC resulting from various coefficients of variation of inputs to TACs, where F(1982) = 0.5

Fishery effort data (%)	Catch at age data (%)	Recruitment data 0%	15%	30%	60%
0	0	0	9	18	39
	10	3	9	18	39
	20	7	11	19	39
	40	14	16	22	40
15	0	13	15	22	34
	10	13	16	23	41
	20	14	17	23	42
	40	19	21	26	40
30	0	32	34	38	51
	10	33	34	38	52
	20	33	35	39	53*
	40	36	37	41	54
60	0	103	104	107	115
	10	103	104	107	115
	20	104	105	108	115
	40	107	108	110	118

* Highlighted cell is authors' personal estimate of current situation

5. SCIENTIFIC PROBLEMS CAUSED BY TECHNOLOGICAL INTERACTIONS AND MULTI-SPECIES FISHERIES

Many fisheries use methods of capture which can and do catch several different species at the same time. The tactics of fishermen may also very reasonably include diversion from fishing the main species sought during a fishing trip to fishing a secondary species when an attractive concentration of this species is found. For example, Lowestoft fishermen usually fish for plaice with one set of gear but may transfer to another gear if a good concentration of cod is encountered and market conditions are right. Thus, whether by accidental capture or deliberate diversion, it is normal for a fishery which generates fishing mortality on one species to generate by-catch fishing mortalities on other species.

These by-catch mortalities can frequently cause conflicts of interest between fisheries for different species. This is particularly likely to happen when the by-catch is generated from intensive small-mesh fisheries for small fast-growing species. By-catches in these fisheries may well be juveniles of other species which should be left to grow on.

Some examples of such conflicts are haddock, which was caught as a by-catch in the silver hake fishery on Georges Bank, groundfish caught as by-catch in Norway-pout fisheries in the North Sea, herring caught as by-catch in sprat fisheries and groundfish caught in inshore shrimp fisheries in the South China Sea area and elsewhere. In shrimp fisheries, discard rates for groundfish as high as 95 percent have been recorded.

Such problems may sometimes be alleviated by restricting the areas in which small-mesh gears may be used or possibly by gear modifications aimed at releasing some species while capturing the species at which fishing is directed.

Where these palliatives are unsuccessful in resolving conflicts, then there may be a need for mortalities generated on both fisheries to be adjusted. There may, for example, be a need for the fishery for the fat-growing species to be reduced to a somewhat lower level than would be optimal were only that fishery considered. Similarly, the species caught as a by-catch may need to have a higher than optimal level of mortality. Thus, even if no biological interactions occur between species, such technological interactions may cause a change of objectives for both species. The choice of new objectives of course falls on the managers, since there must be a compromise between the yield to be had from two different fisheries, and therefore based on economic rather than yield considerations. The scientific problem is, of course, elucidating the consequences.

The problem can become particularly acute where managers wish to prevent any fishing on a species in order to allow it to recover from severe depletion. Strictly enforced such regulations might be very restrictive on other viable fisheries. The haddock on Georges Bank and the North Sea herring are both examples of this problem.

Where by-catch fishing mortality is causing the virtual extinction of a species, the problem can be particularly difficult to solve. An example of the problem is given by skates and rays which Holden (1977) shows can be fished down at quite low fishing mortality rates due to their low fecundity. The common skate (Raja batis) is particularly at risk and Brander (1981) shows that this species has effectively disappeared from the Irish Sea. It may be that, for this species to be conserved, fishing mortality rates on all Irish Sea demersal fish might need to be reduced.

Certainly this example does point out how difficult the choice of objectives for a mixed fishery may be.

The problems posed to scientists by mixed fisheries are often concerned with the extent that by-catch rates might be moderated by given regulations and the consequences of change in mortality rates. A common problem is the definition of main species sought and the true level of by-catch. Unless fairly disaggregated species catch data are recorded for each fleet, the by-catch rate can be apparently increased by the results of separate fisheries being merged.

One solution to the mixed fishery problem tried on Georges Bank was the imposition of a second-tier TAC on all species combined. This was to restrict catches to prevent mortalities on some species being generated to the detriment of other species. In practice, this was difficult for scientists to calculate with any certainty, and the problem might perhaps be better solved by political and economic compromises between the conflicting fisheries.

Although the problems of mixed fisheries show the need for setting objectives which compromise between species, the need is even more obvious where species interactions occur. For example, predation by fish of one species on juveniles of another species is likely to produce a distinct change in the yield of the second species. Clearly its yield may be affected by fishing mortality levels on the first species. An example of this is the increase in the abundance of squid in the Gulf of Thailand which appears to have resulted from a general decrease in the abundance of most other fish species, due to fishing pressure. The scientific problem might be seen as being to define the consequences of particular levels of fishing on each species. This would, however, at our present state of knowledge, be wildly ambitious. The immediate problem may therefore be to indicate possible effects of directions of change in mortality for various key species. A good review of the scientific problems of multi-species fisheries may be found in Mercer (1982) which contains a series of papers given at a Workshop on Multi-species Fisheries held at St. Johns, Newfoundland in 1980.

At a more immediate level, multi-species predation effects do not appear to cause very much of a problem for setting TACs to maintain current mortality levels. This is because much of the predation would seem to be on '0' group fish (at least in the North Sea) and thus research vessel recruitment surveys and commercial catch-at-age data are not much affected by varying levels of predation mortality (Pope and Knights, 1982). Table 12 shows mortalities calculated by their method for a number of North Sea fish stocks.

Table 12 Natural mortalities generated by two runs of the modified cohort analysis

Species	Run	Ages														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cod	1	0.975	0.206	0.104	0.1	0.1	0.1	0.1	0.1	0.1						
	2	0.838	0.227	0.11	0.1	0.1	0.1	0.1	0.1	0.1						
Haddock	1	0.847	0.403	0.242	0.115	0.108	0.104	0.102	0.1	0.1						
	2	0.776	0.407	0.261	0.133	0.120	0.111	0.104	0.1	0.1						
Whiting	1	1.114	0.405	0.149	0.131	0.131	0.131	0.118	0.109							
	2	0.976	0.419	0.191	0.167	0.167	0.167	0.141	0.121							
Saithe	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1			
	2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1			
Herring	1	0.407	0.271	0.260	0.220	0.218	0.219	0.193	0.143	0.143						
	2	0.248	0.291	0.279	0.261	0.259	0.259	0.234	0.142	0.142						
Plaice F	1	0.1	0.117	0.109	0.103	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	2	0.1	0.121	0.118	0.108	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Plaice M	1	0.1	0.117	0.109	0.106	0.103	0.1	0.1	0.1	0.1	0.1					
	2	0.1	0.121	0.118	0.108	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

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REGULATION OF FISHING EFFORT THROUGH VESSEL LICENCES

by

B.S. Brochmann
Director of Planning
Ministry of Fisheries
Oslo, Norway

Has licensing (limited entry) any purpose after the introduction of quotas?

The harvesting of all important fish stocks in Norwegian waters is restricted by quotas, i.e. total allowable catch (TAC). For some species, TACs are determined solely by Norwegian authorities; for others this is done in cooperation with neighbouring countries.

In cases where the fishery is stopped when the quota is exhausted, which is the case in most Norwegian fisheries, vessel licences become invalid because of fear or over-exploitation.

What purpose does licensing have then? The question is appropriate as licensing systems (limited entry) still play an important role in Norwegian fishery policy.

The original argument for imposing licensing schemes has differed from case to case. I shall give you two examples:

Example 1: Restricting trawling for cod through a licence scheme (1936) had at least three purposes: (i) protection of the coastal fisheries; (ii) large and costly trawlers meant that foreign capital gained entry into the fishery; (iii) trawling, it was said, was a threat to juvenile cod.

Today these arguments have only limited validity. The catches taken by Norwegian trawlers do not influence to a significant degree prices on the world market for fish. The extended mesh size in the cod-trawl (minimum 135 mm from 1 January 1983 in the Norwegian zone north or 64°N) means that trawling no longer has the same negative effect on the young cod. In addition, since 1974, cod-trawling has been regulated through a separate quota fixed for trawlers. Even without licensing, the catch taken by trawlers would remain at the same low level.

Nevertheless, a licence scheme is maintained. Why? (1) Since there is excessive capacity in relation to the quotas fixed for trawlers, the situation would be even worse if new trawlers were allowed to enter the fishery. Present economic conditions, however, make the possibility of new projects seem remote anyway. But conditions often change and licensing is maintained as a form of "insurance". (2) The geographical distribution of licences provides an instrument to ensure a certain supply and distribution of raw fish to regions that are particularly dependent on fish as raw material for processing.

Example 2: The licence scheme for the purse-seiner fleet was implemented in 1973 following a remarkable increase in catching capacity from 1970 to 1972. The central authorities feared over-exploitation of the most important stocks. It was also felt that, if the high rate of investment in this sector were to continue, economic disaster would follow, either because of depleted stocks or (if quotas were to be implemented and respected) because of severe over-capacity.

Biological considerations are no longer an important argument for imposing the licence scheme, however, because every year since 1977 a total quota (TAC) for capelin, which is the most important stock for the purse seiners, has been negotiated with the Soviet Union. As anticipated, quotas have meant that over-capacity would be a prominent feature of the purse-seiner fleet.

Nowadays the licence scheme for purse-seiners has two main purposes: (1) To improve the economy of this fishery by limiting the number of vessels involved in taking the quotas. (In fact, the number of vessels is steadily decreasing, since concentration of the cargo capacity of two small or medium size vessels in one larger one is permitted.) (2) The cargo capacity registered by the licence is the basis for dividing the capelin quota between the participating vessels.

Many fishery politicians refer to a third purpose for the licensing of purse-seiners: that is, to influence the regional distribution of such vessels, in order to allocate job opportunities to coastal areas which seem to have greatest need for them. The possibilities for steering the geographical distribution of licences, however, are in practice very limited.

One argument for having a licensing arrangement is of a more political nature: it is far easier to enlist fishermen's support for the necessary quota regulations when the fishing fleet is not expanded excessively in relation to the proposed quotas.

On account of protests from fishermen, substantial over-capacity in relation to the national quotas may force the fishery authorities to seek increased TACs (beyond the level recommended by biologists) when international negotiations over TACs take place. If over-capacity prevails in several countries, the pressure for higher TACs may become dangerous. This can be avoided to a certain degree by implementing limited entry.

For the period 1979-82, the Norwegian Government adopted a scrapping programme for certain groups of fishing vessels, in an attempt to get rid of over-capacity. The purpose was not only to make it easier for the politicians to fix more restrictive quotas, but also to lower costs in fishing. This would reduce the need for governmental support. The scrapping programme included only vessel groups subject to limited entry. Without entry control, new vessels could be expected to replace the capacity withdrawn through scrapping. Licensing thus has a legitimate use also in cases like this.

Still important groups of vessels in the Norwegian fisheries are not subject to limited entry. The fleet of small and medium-size coastal vessels operating in the cod fisheries in northern Norway is regulated through other measures such as a ban on fishing during certain periods spread over the year. This fleet is also subject to gear control (maximum number of nets per vessel). The purpose of these measures is to reduce the catch to the level fixed on the basis of international agreements.

This illustrates that we are able to restrict fishing effort by administrative means other than licensing; but, if our objective is to restrict the amount of production factors involved in taking the quotas, in order to increase profitability, licensing schemes can be an appropriate instrument. In another paper, which will be presented later, I shall discuss the appropriateness of using licensing as a means of furthering profitability in the fisheries.

Can limited entry replace a quota system?

I shall now turn to the following question: can a comprehensive licensing system replace a quota system? Is it possible for a licensing scheme to achieve biological (conservational) objectives in addition to the economic and distributive objectives already mentioned? The answer is that, for stocks which might migrate between the zones of several nations, licensing, even when used by all relevant nations, is not sufficient to avoid depletion of such stocks. The nations must in addition cooperate and agree on a TAC and on the sharing of it.

If we know our national share of the TAC, however, can licensing then be an appropriate instrument to avoid over-fishing of the national quota? The same question of course applies when we consider stocks found within the zone of one nation only and solely fished by vessels from that State. My answer to this question is: "Yes, it is possible to use licensing as a measure to keep the catch within national quotas; but, at the same time, it is far from an advisable policy if not combined with measures of an economic nature".

I shall give you some arguments in support of this view:

(1) The typical case is that a licence scheme is imposed after a stock has been too heavily harvested, in order to prevent its further depletion. The introduction of a licence scheme normally means that licences are issued to the vessels already active in this fishery but not to newcomers. Restoring the stock, however, requires reduced fishing effort. To achieve this (disregarding the auctioning of an appropriate number of licences), you must introduce a system of quotas, causing some or all of the vessels to be laid up for certain periods of the year or transferred to other (less profitable) fisheries.

(2) Even if the licence scheme is implemented at such an early stage that over-utilization of the stocks has not yet occurred, continuous technological progress will increase the catching capacity of the fleet. Sooner or later even the restricted number of vessels will be able to deplete the stock or over-fish the national quota.

(3) TACs and national quotas will often change from year to year, depending on the stock situation. The catching capacity of licensed vessels, however, obviously will not change in conformity with changes in the recommended catch volume. Instruments other than a licence system, therefore, are needed. The same kind or argument is valid even if the national quota remains stable, as the catch rate may vary from year to year irrespective of the size of the stock.

(4) A licence scheme has several disadvantages. It retards the flexibility of the fleet, for example, reducing its ability to adapt to new conditions. It also renders the recruiting of new and young fishermen into the fishery more difficult.

(5) The management of a licence scheme is often a vast administrative undertaking. One well-known difficulty is the handling of applications for replacing a licensed vessel with another, better suited (and always a little bit larger) vessel. I may also mention the questions which arise in connection with buying and selling licensed vessels. Should a licence be transferable?

So much for the disadvantages and shortcomings of a limited entry system. Combined with quotas and monetary measures, however, a licensing system may be very appropriate. A levy on catch or a licence fee, in some cases combined with a buy-back programme, may possibly solve most of the problems mentioned.

Licensing: Still a necessary supplement?

Licensing systems are still considered to be very important instruments in Norwegian fishery policy. The Fishermen's Association has even suggested that all types of fishery should be subject to licensing as a means of regulating the fisheries. In recent years, however, the central authorities have become more aware of the many disadvantages connected with licensing as a regulatory measure. In addition, the original purposes for imposing the several licence schemes are nowadays to a large degree served by an array of new instruments, mainly quotas.

As long as over-capacity prevails, however, and the level of investment is not controlled in one way or another, the licensing programmes are instruments which may be convenient to have at hand in order to restrict increases in capital and running costs. In addition, I may remind you of the convenience of implementing a licence scheme before the introduction of a scrapping programme, and of the pressure for increased TACs that may arise when catching capacity is not restricted through licensing.

Licensing means that administrative bodies make decisions which would otherwise have been determined by market mechanisms. Were it feasible to consider a licence as a commodity, subject to buying and selling, the serious disadvantages connected with licensing probably could be avoided.

TERRITORIAL USE RIGHTS IN FISHERIES

by

Theodore Panayotou
Faculty of Economics
Kasetsart University
Bangkok 9, Thailand

Summary

This is the preliminary report of a small Workshop held in Rome, 6-9 December 1982. The Workshop was called to examine the concept of territorial use rights in fisheries (TURFs) and the possible use of such rights in the management of small-scale fisheries. The possibility of using TURFs for fisheries management derives from the recent increase in knowledge about traditional territorial systems that continue to exist in a large number of areas throughout the world. The Workshop was exploratory in nature. This preliminary report recounts the highlights of the discussions on the definition of TURFs and on the evaluation of their use with regard to criteria of efficiency and equity.

1. INTRODUCTION

In preparation for the FAO World Conference on Fisheries Management and Development, FAO held a Workshop on Territorial Use Rights in Fisheries (TURFs), in Rome during 6-9 December 1982.

The general objective of the Workshop was to examine the concept of territorial use rights as a means of achieving fisheries management goals. The specific objectives were:

(a) To provide a definition of TURFs

(b) To evaluate the use of TURFs with regard to criteria of efficiency and equity

(c) To identify and assess the conditions affecting the creation or maintenance of TURFs

(d) To suggest needs for further examination

Because of the exploratory nature of the Workshop, a formal report of the detailed proceedings is not warranted at this stage. Moreover, the workshop deliberately refrained from making any formal recommendations except to call for further investigation of traditional territorial use rights and of the potential for strengthening or establishing TURFs in specific cases. The present paper is an account of the highlights of the Workshop as seen by the author rather than a comprehensive formal report of the proceedings. It is intended for consideration at the Expert Consultation on the Regulation of Fishing Effort and for use in further research and testing.

2. TERRITORIAL USE RIGHTS IN FISHERIES: A DEFINITION

As the term clearly suggests, Territorial Use Rights in Fisheries or TURFs involve a certain territory and certain rights of use relating to fishing within that territory. These features, however, are necessary but not sufficient elements of a TURF; for instance, the right (of every nation) to fish in the open seas (a territory) does not constitute a TURF. Other elements are necessary. One element

refers to the contents of rights: in addition to the right of use a minimum degree of exclusivity (that is, the right to exclude others) is necessary. In that sense, a country's Exclusive Economic Zone (EEZ) is a TURF as it implies the right of use by nationals of the resources within a given territory and the right of exclusion of non-nationals. Yet, such a broad definition of TURFs is hardly meaningful from the standpoint of fisheries management. At the other extreme, a privately owned oyster-bed may be considered a TURF as it involves a territory, and rights of use to the exclusion of others. However, such a TURF is trivial since it refers to private property which is presumably properly managed. This brings us to the last essential element of TURFs as defined by the Workshop: that is the rights of use and exlclusion defined over a given territory are held by a community or a collectivity with socially integrating forces. This last requirement disqualifies both EEZ's and privately held property as TURFs.

Thus, TURFs may be defined as community held rights of use (or tenure) and exclusion over the fishery resources within a specific area and for a period of time. Accompanying these rights might be certain responsibilities for maintenance and proper management of the resource base, as well as restrictions on the excercise of the rights of use and exclusion.

Although a number of other definitions of TURFs were offered by the participants, it was generally agreed that the aforementioned elements, that is community, territory and a set of rights (including a "satisfactory" degree of exclusivity and tenure) and responsibilities are the essential (minimum) descriptive elements of TURFs. It was felt that prescriptive elements should not be included in this (broad) definition of TURFs.

3. TRADITIONAL TURFS AND THE PROBLEMS OF THE OPEN ACCESS FISHERY

Territorial Use Rights in fisheries, in the sense of community-held rights of use over resources within a territory at the exclusion of others have been known to exist for centuries. Examples of traditional TURFs are still found today, among other places, in Brazil (Cordell, 1980), Sri Lanka (Alexander, 1980; Fernando et al., 1982), Papua New Guinea (Johannes, 1982), Oceania (Johannes, 1978; Akimichi, 1981), Ivory Coast (Garcia, per. comm.). While many of these customary rights are now crumbling under the pressures of population growth, technological change and commercialization of subsistence fisheries, they have provided for centuries a check on the expansion of fishing effort and still do where they are sanctioned by governments, as in the case of Japan (Asada, Hirasawa and Nagasaki, 1982; Comitini, 1966).

The growing interest in TURFs stems from their potential role as management tools for fisheries suffering from or threatened by the ills of open access (overfishing, crowding, excessive effort) and yet refractory to conventional management (e.g., prohibitively high monitoring and enforcement costs). A prime example is the case of remote, scattered, and fluid small-scale fisheries.

As it is widely accepted, unrestrained competition in open-access fisheries leads to expansion of effort (employment of capital and labor) far beyond the level which maximizes either economic benefits or sustainable catch, to the point where costs become so high and catch so low that no net economic benefit (or resource rent) is being derived 1/. This amounts to a waste both in terms of the resource and in terms of capital and labour. A reduction of effort would reduce fishing costs and (might) also increase catch and gross receipts resulting in net economic benefits (or rents). The economically optimal level of effort is where economic benefits or rents are being maximized. Such a reduction of effort and its control at the optimal level might be attempted through a number of management tools or regulations such as catch quotas, gear restrictions, seasonal and area closures, fishing effort controls, taxes and licences. Apart from possible ineffectiveness and induced inefficiencies, the introduction, monitoring and enforcement of these regulations involves considerable costs which under certain circumstances are prohibitively high, in the sense that they exceed the expected benefits from regulation (i.e., the potential resource rents). This is particularly true of

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1/ Not everybody would agree on the last part of the sentence, as one might be inclined to think that even at open-access equilibrium there are some benefits from fishing in the form of production of some protein and employment of labour. Yet, if all inputs (including labour) and outputs (catch) are priced at their true (social) opportunity costs, the society derives no benefit at open-access equilibrium.

multigear multispecies small-scale fisheries consisting of large numbers of small and fluid units scattered across thousands of kilometres of remote coastlines. The difficulties and costs of designing, implementing and enforcing regulations over such refractory fisheries are further aggravated by the severe budgetary and administrative limitations of the governments concerned.

Under these circumstances, alternative management tools which hold a promise for lower implementation costs through self-management deserve serious consideration. It is in this light that the potential of Territorial Use Rights as a management tool is being studied.

4. EVALUATION OF TURFS AS POTENTIAL MANAGEMENT TOOL FOR OPEN-ACCESS FISHERIES

TURFs as a management tool for overcoming the problems of open access should be evaluated in terms of both efficiency and equity. A TURF is an "efficient" management tool if it provides the means for generating or increasing the net benefits from a given fishery (or part of the fishery). A TURF is "equitable" if it provides the means for improving the distribution of benefits within the community from the exploitation of the fishery. A third attribute of TURFs as a management tool is their possible contribution to the wider community (society) in terms of environmental preservation, resource conservation and possible generation of government revenues.

4.1 TURFs as a Means for Increasing Fishery Net Benefits

The establishment of a TURF may help generate or increase net benefits from a heretofore open-access fishery in a number of ways:

(i) By excluding outsiders from the territory of the TURF

(ii) By controlling the use of labour and capital within the territory of the TURF

(iii) By dealing with spatial and other externalities partly through internalization and partly through coordination with adjacent TURFs which share the same stocks

(iv) By investing to enhance future returns, negatively through increased incentives to avoid depletion and positively through community works such as landing places, artificial reefs, aggregation devices and aquaculture

(v) By providing flexibility to adjust to changes in technology, markets, resource characteristics and the socio-economic structure of the fishing community (flexibility includes the divisibility of the TURF).

However, these potential means or advantages of TURFs (over a situation of open access) for generating benefits are by no means automatic, certain or costless. To each, are "buts" and "ifs" attached which are discussed in some detail below.

Exclusion of outsiders

Under contemporary conditions effective exclusion of outsiders from a given territory necessitates an external authority to acknowledge and reinforce existing boundaries and rights or to establish and protect boundaries and rights for new TURFs. This requires a decision to recognize an existing pattern of wealth distribution or the politically more difficult decision to redistribute wealth. The latter is also technically difficult in situations where stocks are mobile and there is no clear relationship (identity) between the biological unit (stock) and the socio-economic unit (community). The creation of a TURF should be easier where social and resource territories are "coterminus" and/or where redistribution of wealth is a well-accepted function of government.

However, despite the need of external authority to sanction and protect the boundaries of TURFs, management, monitoring and enforcement costs may be substantially reduced by the creation of TURFs. Instead of having to introduce detailed management regulations and to monitor the actions of thousands of scattered fishing units, the government's role is reduced to resolution of inter-community conflicts while detailed management, monitoring and enforcement activities are relegated to the internal social mechanisms of the community. There would also be little need for monitoring of

outside encroachments by the external authority since it would be in the best interest of the members of each TURF to guard jealously their resources and report such encroachments. On the negative side, creation of TURFs might lead to intercommunity rivalry and warfare with the need for continual government presence to maintain law and order.

Control over labour and capital

Whenever profits exist under open access conditions, there is tendency both by outsiders to enter the fishery and by insiders to increase effort (employment of labour and capital) in order to increase their share of the profits. Thus, even if entry from outside the TURF is stemmed still the fishery may continue to suffer from the ills of open access if there is no control of the amount of labour and capital employed by the members of the TURF. Yet, control of the use of labour and capital is necessary if "capital-stuffing" and "racing" (characteristics of open-access fishery) are to be prevented, fishing costs held down and overfishing avoided.

A TURF may serve as a means of controlling the use of capital and labour through appropriate incentives (and penalties) discouraging the use of one or both of these inputs or by establishing appropriate sharing mechanisms among members which promote more the cooperative than the competitive spirit. A TURF may also help break the nexus between capital and labour by reducing the competition for ever more modern/efficient equipment or even by encouraging common ownership of vessels and gear. A TURF may also facilitate controls over the type of capital equipment used (e.g., mesh size) and a curb over the use of destructive fishing methods such a poison and dynamite.

However, TURFs cannot always determine the "optimum" amount of fishing effort especially with fluctuating stocks and rapidly changing technological and economic conditions. TURFs may also have difficulties enforcing controls although they are likely to be an improvement over both open-access and centralized fisheries management because of the social mechanisms available in a closely-knit community such as peer-group pressures, social sanctions, elders leadership, etc. Another difficulty to be faced by TURFs is in deciding who, from within the community, would be allowed to enter the fishery and with what amounts of capital and labour. The question of "membership", that is, who would be allowed to fish or to share the benefits from the fishery, is a very important one which was not resolved to the satisfaction of the workshop and calls for further study and discussion.

While the creation of TURFs may help reduce monitoring and enforcement costs, it might result in loss of economies of scale in obtaining information concerning the stocks and the fishery wide optimum amount of effort. Even within the TURF there would be costs of acquiring information as to how much and what kind of fishing effort to apply. In certain situations (mobile species or widely fluctuating stocks), the community would need scientific information and outside assistance for determining the appropriate fishing rate.

Dealing with externalities

In an open-access fishery, where each fisherman acts as a separate economic and "management" unit, the actions of one fisherman have an effect on the catch and the returns to all other fishermen who exploit the same stock. The individual fisherman does not perceive this external effect (or externality) or even if he does, he has no incentive to take it into account. The racing, crowding, capital stuffing, and falling catch per unit of effort are different manifestations of the externalities which open-access fishermen impose on each other. TURFs deal with the externalities between their members by internalizing them into one "management" unit, the TURF, within which members are forced to take into account the effect of their actions on each other's catch and returns.

However, unless the community and the resource stock are "coterminus", some externalities would remain outside the TURF. With shared stocks and migratory species many externalities cannot be internalized unless the TURF is large enough to encompass the entire stock; such a TURF is unlikely to be functional as a management unit since it lacks the integrating social forces of a closely-knit community. While a TURF cannot internalize all externalities, it does provide an entity which can coordinate with adjacent TURFs over shared stocks (including migratory fish, shared resources and water quality). Such externalities might be best tackled through the concept of "TURFs within TURFs" (smaller precisely defined TURFs within larger less precisely defined TURFs) and fisheries coordination committees similar to those established in Japan with both a coordinating role and authority for mediation and arbitration. But, if the externalities left outside the TURF (to be resolved

through coordination with other TURFs) are more significant than those which have been internalized, the TURF is unlikely to be successful as a management unit. If the members of the TURF perceive that outsiders' actions have a more direct and pronounced effect on the state and productivity of their portion of the resource (and hence on their future profits) than their own actions they are unlikely to behave differently than open-access fishermen. This suggests that the concept of the TURF is likely to be most successful in the case of sedentary or not very mobile resources such as seaweed, oyster and clam beds, and in the case of resources within well-defined geographical areas such as reefs, tidal lands, swamps, self-contained bays, lagoons and river estuaries. The concept may be more difficult to apply to more mobile resources, but may still be more successful under the right conditions.

Investing to enhance future returns

The creation of a TURF itself may act as an incentive for members to stop regarding the fishery as an extractive industry and begin treating it as a renewable resource, whose productivity can be enhanced through investments including the abstention from fishing in certain areas and seasons (e.g., spawning). For such a change of attitude and behaviour, however, there needs to be a clear perception of the relationship between present actions and future returns. The clearer this relationship is, the stronger the incentive for self-management/self-enforcement. The TURF's membership or leadership may reinforce this change of attitude and behaviour through regulation (e.g., close areas and seasons) as well as through incentives. Again, the design of regulations and incentives involves costs, in terms of information on yields, fishing effort, expenditures and revenues.

A TURF may also facilitate or promote community investments in fishing infrastructure (landing places, artificial reefs, fish aggregation devices) as well as in fish culture as a supplementary source of income and employment. TURFs may increase government willingness to support investments, as well as to organize the community for demanding such assistance. Important considerations with respect to such investments are the security of tenure (sufficient time to pay-back and earn a satisfctory return) and possible leakages of benefits to outsiders which might diminish the incentive to undertake such investments.

Flexibility to adjust

Many management tools and regulation often fail over the long-run, despite an early success, because of rigidity, that is, lack of flexibility to adjust to changing socio-economic technological and resource conditions. Moreover, centralized fisheries management takes into account the average conditions in a fishery rather than the particular circumstances of each specific location/community. In contrast, TURFs have the advantage of being both localized and flexible enough to take into account local circumstances and to adjust to a changing bio-socio-economic environment. The characteristics of both the resource and the fishing community change over time and so do markets and technology. TURFs can evolve or be modified through adjustments in territory, rights or membership to account for these changes in circumstances.

However, for such flexibility it might be necessary to incorporate in the concept of TURFs the ability to lease or sell shares (transferability) and the ability to divide or merge the TURF with adjacent TURFs, all of which entail risks and call for safeguards to preserve the essential elements of the system.

4.2 TURFS as a means for improving the distribution of benefits

TURFs may help improve the distribution of benefits among the members of a fishing community in a number of ways:

(i) By improving local employment opportunities

(ii) By increasing local income, consumption and nutrition and evening out fluctuations in income

(iii) By making possible the preservation of community social organization and reducing intra- and inter-community conflicts

(iv) By promoting social mobility and "learning by doing"

Again, these benefits are by no means automatic, certain or costless; there is certain likelihood that they will be realized if certain conditions are met or courses of actions are taken as discussed below.

Improving local employment opportunities

Following the creation of a TURF in a given community, the employment opportunities within the community might increase while those outside the community might decline as a result of the exclusion of outsiders. Employment opportunities within the community might improve for a variety of reasons: (a) transfer of employment opportunities from outsiders to insiders through resource redistribution (e.g., exclusion of trawlers from coastal resources); (b) inducement of a more rational input mix with higher labour component as a result of reduction of capital stuffing, termination of subsidized mechanization and increased interest in retained benefits to the members of the TURF as a group; (c) use of part of the generated rents (see Section 4.1) to expand employment opportunities within the community (e.g., aquaculture, fish aggregation devices and other community-supported projects); and (d) improvement of secondary employment opportunities (local processing, marketing, etc.) through an enlarged catch (following the recovery of the fishery) and through deliberate action to encourage local processing, etc.

However, for such benefits to be realized it would be necessary to set appropriate criteria for TURF membership and/or for sharing of benefits. This becomes more evident in the earlier stages of the life of a TURF if (primary) fishing employment must be reduced to allow the fishery to recover. Earlier on, the issue is who would pay the cost for the fishery's recovery (through exclusion from employment) and later on, as the fishery recovers and employment opportunities are improved, who would share in the benefits (through better-paying jobs).

Membership in the TURF, number of shares per member, and their transferability would determine who would benefit from the improved employment opportunities. Setting up criteria for membership is not an easy task; residing in the community, being an active fisherman for certain period of time, depending significantly on fishing, abiding by the community rules, etc. are possible criteria. Similarly, it is necessary to set up criteria and procedures for termination or transfer of membership. These issues arise not only in relation to the distribution of employment benefits but also in relation to the distribution of all other benefits (and costs) from TURFs. But, other things being equal, increased employment opportunities would mean a better distribution of benefits since those with the least amount of capital are likely to benefit most from additional employment on improved terms.

Increasing local income, consumption and nutrition

The creation of a TURF might increase local incomes in a number of ways: (a) by acquiring a larger share of resources following wealth redistribution (see section "Exclusion of outsiders" above); (b) by generating rents, captured in part or entirely by members, through fishery management (see Section 4.1); (c) by retaining a higher percentage of generated income within the community; and (d) by facilitating more integrated development, i.e., community control over processing, marketing and distribution, and further enhancing local economic linkages.

Increases in local incomes are counted here as contributors to improved income distribution based on the presumption that (small-scale) fishing communities under conditions of open access are at the bottom of the income scale. The outsiders who are excluded by the creation of the TURF are, presumably (large-scale), trawler and purse seine owners which are higher up on the income scale. To the extent that low-income people (actual or potential fishermen) such as migrants are denied access to the fishery by the creation of the TURF, income distribution deteriorates. Again, the membership and the nature and distribution of shares among TURF members are deciding factors of the distributional outcome of TURFs. Transferability of shares, internal power structure and equalitarian values of the community will also play a role in the intracommunity distribution of benefits. An important issue requiring further study is the appropriate nature of the share: a share in net benefits, a privilege of access (licence), or a vote in decision making?

Other difficulties related to "increasing local incomes" is the trade-off between efficiency and distribution: efficiency requires that shares are transferable but transferability (and flexibility) introduce difficulties in assuring that incomes remain local. On the other hand, the system may break down if a substantial portion of the increased income consists of rents. Rent differentials with other TURFs and non-TURFs would create pressures for enlarging access, increasing considerably enforcement and policing costs. In many cases, rent differentials may not be great, but where they might be, the outside pressure may be eased by taxing away part of the rents which would contribute to both fairness and efficiency (reduction of policing costs).

The creation of TURFs might also have a positive impact on local fish consumption (and hence nutrition) over and above that which might be induced by higher local income. This might be the result of wider participation of the benefits from the fishery within the community (improved distribution) or a "by-product" of local processing.

The impact of TURFs on the fluctuations of income levels is rather ambiguous. On the one hand, the creation of TURFs might even out fluctuations through resource management and induced social sharing and, on the other, it might worsen fluctuations by confining fishing operations within a more limited area than under open access.

Preserving social organization and reducing conflicts

Community organizations and social relationships including the spirit of cooperation and sharing rather than antagonism and conflict may be promoted by the creation of TURFs in which members have common and more or less equitable interests. Community organization and social relationships are likely to contribute to improved distribution of benefits from communal resources and opportunities which extend beyond the fishery. Moreover, a healthy community organization with democratic decision making and amicable social relationships may be valued for its own sake.

A TURF may help reduce intracommunity conflicts because of the sense of greater common interest which it is likely to bring about. However, this requires a sense of security of tenure and "fairness" in the distribution of benefits (or at least opportunities) as well as a set of procedures for orderly and peaceful resolution of occasional conflicts. Intercommunity conflicts may also be reduced through coordination and a set of formalized procedures for mediation and arbitration for dealing with externalities. The frequency and severity of intercommunity conflicts would depend on the size of TURFs (or more precisely the relative sizes of the social and the biological units) and the sensitivity and certainty with which the boundaries are drawn. Intercommunal conflicts may be exacerbated by unfair distributional decisions, pervasive externalities and wide rent (or income) differentials brought about by changes in resource characteristics or economic parameters.

Promoting social mobility and "learning by doing"

Social mobility might be enhanced by the creation of TURFs to the extent that crewmen and landless labour in the community acquire shares in the TURF which enable them to derive income from property beyond the income from their labour. On the other hand, the TURF may facilitate the loss of rights to the resource by allowing or even encouraging the sale of shares (including forced sales) which might result in concentration of shares in few hands and "proletarization" of the marginal fishermen (downward social mobility).

TURFs may encourage "learning by doing" in a variety of ways including community development, familiarization with new technology and access to a broader capital market. Community tenure over a resource may help develop community responsibility and improve existing social organization (see Section "Preserving social organization and reducing conflicts") or even provide a new form of social organization which can be built on. TURFs may facilitate acquisition and use of new technology because: (a) large-scale operations may be excluded allowing the community to fill the gap; and (b) security of tenure and collective control may encourage use of new gear and possibly investments in aquaculture. TURFs may promote access to a broader capital market by providing greater status and security (property) to fishermen as well as by opening up opportunities for new technologies provided that there are sufficient indications of high future returns.

4.3 Improving benefits to society

A TURF may operate in a way beneficial not only to its members but to the society at large as well, by conserving resources, preventing environmental degradation and possibly generating some government revenues. TURF members have incentives to manage the fisheries and conserve ("optimally use") the resource because of security of tenure or at least a clear and lasting association between the state of the resource and their incomes. However, technical information for proper management may have to be provided by external (government) sources.

It is to the best interest of TURF members to prevent damaging alterations of the environment such as water pollution, felling of mangrove forests and destruction of coral reefs within their territory because such actions would have a pronounced negative effect on their livelihood. Preservation of the environment contributes to non-fishery uses of the territory and adjacent areas (e.g., for recreation and tourism) and to the general ecological stability of area. TURFs may promote social responsibility by giving fishermen more effective voice in planning and decision making.

Finally, TURFs, or at least the most successful of them, may produce revenues for the society at large: (a) by saving on management and enforcement cost; (b) by reducing the need for costly welfare/development assistance to depressed fishing communities; and (c) by generating substantial resource rents, part of which may be creamed off by the government through appropriate levies.

5. CONCLUDING REMARKS

In concluding, it should be noted that our examination of TURFs was based on the assumption of community rather than private individual controls. The Workshop envisaged that an overall benefit of a TURF is that it allows the government to turn over to the local community many of the functions and responsibilities of management (including the determination and distribution of benefits, the acquisition of information) and enforcement.

While there was more or less consensus on the potential benefits and difficulties of TURFs as a management tool, as described above, the workshop recognizing the paucity of knowledge on the subject refrained from making any recommendations for the establishment or promotion of TURFs at this stage. It was, rather, concluded that governments are well advised to examine and give careful consideration to traditional TURFs and their potential contemporary relevance as tools for fisheries management and rural development.

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FISHERMEN'S QUOTAS: ONE METHOD OF CONTROLLING FISHING EFFORT

by

Fernand J. Doucet
Toledo
Ontario, Canada

1. INTRODUCTION

Recognition of the common property nature of fish resources is probably as old as the history of fishing itself, although the elaboration of the common-property resource concept and its built-in shelf destructive elements is more recent. Similarly, allocating access to a piece of common property to an individual or a community was an accepted practice many centuries ago with respect to common land. It is at least one hundred years old with respect to certain fishing rights. One reads about fishermen on the east coast of Canada being given rights to certain "berths" for setting sardine weirs and on the coast of newfoundland for cod traps. Although there were no legislative limits to the number of such "berths", there were natural limits and, while some such rights were for one season and allocated by lottery, many were in perpetuity and deeded from father to son.

What distinguishes the more recent discussions of the common-property nature of fishery resources from earlier concerns is the conclusion that open access to such resources leads to excessive investment, reducing average returns, and to the depletion, if not the eventual destruction, of the resource. Some fishery managers on Canada's Pacific Coast recommended the granting of quasi-proprietary rights over certain salmon berths early in this century. It was not until the second part of the century, however, that the destructive nature of open access to a common-property resource was formalized in the economic literature.

Most fishing countries accept the need for restricting access and do so by requiring all participants to obtain licences. Although many fisheries are open to all who wish to pay the (generally modest) licence fees, limited entry is becoming more and more common every year. Restricting the number of licences is reasonably effective in small-boat artisanal-type fisheries, where all units are standard and participants are not able to replace their fishing boats with larger and more powerful vessels. In most fisheries, however, limiting the number of licences does not necessarily control the amount of the resource that the licensed participants are able to harvest.

As one participant tries to increase his share by investing in more powerful catching gear, others follow with predictable results. To deal with this problem, fisheries management authorities have placed restrictions on the amount and type of gear, the size and fishing power of the vessels, on mesh sizes, on seasons, on annual quotas by species and fishing zones, on the volume of the catch by vessel trip, by week and by month. More recently, fisheries authorities have allocated an amount of fish to a fishing enterprise in the form of a quota which the enterprise can fish as if it had title to it.

The purpose of this paper is to discuss the concept and practice of controlling fishing effort by creating quasi-proprietary rights for fishing enterprises in the form of individual catch quotas. For purposes of this paper, a "fisherman" is a fishing enterprise. The owner of the enterprise may be an individual fisherman who owns his fishing vessel, a person who owns a vessel but does not fish, or a corporate entity which might be a public or private company or a cooperative that owns one or more vessels. The enterprise could, of course, also be owned by a partnership or a consortium.

2. CONTROLLING FISHING EFFORT

The principal reason for controlling fishing effort on any fish stock is to control the catch per unit effort which in large measure determines the returns the fishing vessel can obtain from exploiting the stock. There are different methods of controlling fishing effort which can be divided into two categories: those that control inputs and those that control the output. The first category would include at least the following: restrictions on the size and power of the vessel; the amount and type of fishing gear; the kind of technology to be used; and the number of days a vessel is permitted to fish. The second category would include the following: an allocation of fish to each enterprise in the form of an annual quota; a limit of so much fish per fishing trip or per week or per month; and a limit on the number of trips per selected time periods. Both categories place limits on the number of units licensed to participate in the fishery.

2.1 Controlling inputs

Until now the methods of controlling fishing effort have been from the first category. For those fisheries where bottom or pelagic trawls are used, the emphasis has been on restricting the number of fishing vessels, their size and/or fishing power. For some fisheries this works well enough, provided that the authorized harvesting levels or total allowable catches (TACs) are set at a conservative level. This method of controlling fishing effort is considered by many to be the easiest to implement and to police. In practice, however, there are difficulties.

The estimated increase in catching capacity resulting from technological improvements alone has been estimated at about 10 percent per year for the Canadian wet-fish (ice trawler) trawler fleet. Replacement vessels, even with the same horse power and of the same dimensions, can catch at least 50 percent more fish than the replaced vessels.

In Canada, where only the length of the vessel was limited, new vessels can catch more than twice the amount of fish that the retired vessels of the same size could catch.

The most serious drawback in controlling fishing effort by restricting vessel fishing power is that it does not reduce the incentive to over-invest but rather the opposite. There are few species or stocks that do not have seasonal fluctuations in their abundance and this leads to fiercely competitive effort by each fleet to obtain its share in the shortest possible time. In theory, this would appear to be the sensible thing to do: fish when catches are rates are at their highest. In practice, however, the results may be less satisfactory. Very high catch rates make it difficult for the crew to handle the fish properly so that generally poorer quality fish is landed. In Canada, where the trawler fleet is owned by the processing companies, larger volumes and poorer quality create inventory financing problems because of the inability of the market to absorb the product quickly enough. Poorer quality and high inventory costs thus tend to offset the gains from the higher catch rates. The Canadian experience with large trawlers in the northern cod fishery in 1980 and 1981 is a perfect example of the results of this type of competitive fishing.

Another disadvantage of controlling fishing effort by controlling fishing power is that it tends to encourage fixation on quantity, to the detriment of fish quality. Although the problem is less serious for freezer than for wet-fish trawlers, the tendency is there just the same. This tendency, in Canada at least, is strengthened by crew-share arrangements where the share is calculated in part on the basis of price per pound of fish landed.

Another serious disadvantage of controlling fishing effort by limiting fishing power is the restriction that competitive fishing places on the investment and operational decisions of the vessel owner. He cannot purchase the most efficient vessel but rather the vessel that will get him the largest share. Nor can he decide when to fish a particular stock because if he does not fish when the others are fishing he will not get his share.

In some fisheries, such as those for herring or mackerel, where seining is used, it is the size of the seine and the carrying capacity of the vessels that determine the fishing power of the enterprise. Similarly, in lobster and crab fishing, it is the number of traps that is the important factor.

Controlling fishing inputs to control fishing effort has been the principal method used in most fisheries in the majority of fishing countries. Generally speaking, the method has been successful in preventing the depletion of fish stocks, when used in conjunction with annual TACs. It has failed to reduce the incentive to over-invest and it has tended to increase the competitive race to harvest the available resource.

2.2 Controlling the output

In spite of the obvious failure of the attempts to control fishing effort by restricting inputs, fishermen are generally reluctant to consider restricting their output as an alternative. In part this is because of the competitive nature of the hunt for wild fish stocks where each hunter considers himself either smarter or luckier (or both) than his competitor. Furthermore, as the volume of his catch is more visible than its value, the more fish he lands the more successful he is considered to be by his peers. Hence, placing an upper limit on his catch in the form of a "quota" is not psychologically very attractive to him unless he happens to be at the lower end of the volume scale.

Attempting to control fishing effort by restricting the output of each fishing enterprise is of much more recent origin as a tool of fisheries management. Although the principle of enterprise quotas is well understood by most people associated with the fishing industry, its practice is much less so. This is not surprising, as few people have had direct experience in its application. Moreover, the few fisheries where individual enterprise quotas have been established have not involved large numbers of enterprises. They have generally been established, as a result of some crisis or other, under difficult time and resource constraints. In many cases, the fishery concerned was not the only or indeed the principal fishery of the enterprise. Where it was the principal fishery, the fleet was generally much in excess of the capacity required to harvest the resource, and the resource itself inadequate to provide for viable operations. It is difficult, if not impossible, under such circumstances to ensure that the enterprise quotas are established in a way that will ensure their success.

The advantages of enterprise quotas as a mechanism for controlling fishing effort are that: (a) they remove or greatly reduce the incentive to over-invest; (b) they eliminate the need to compete for a larlger share of the resource; (c) they help to avoid gluts by making it easier for fishermen to fish to market requirements; and (d) by de-emphasizing volume, help to remove some obstacles to landing better quality fish.

There are, however, certain disadvantages: cheating on volume landed is easier and more attractive; policing is more difficult; the system is not practical for small-boat fisheries where the number is very large; the catch is landed at many ports and the vessels fish several species in the course of one season; and finally it can only be implemented successfully with the acceptance and full cooperation of the fishermen involved. The latter stipulation makes it particularly difficult to apply in areas where the fishermen are not organized in some formal association, union or cooperative.

3. THE IMPERATIVES OF ENTERPRISE QUOTAS

Enterprise quotas, like any other management tool, must be considered within the context of the whole structure of the industry and the fishery management system. Some of the imperatives of enterprise quotas are the same as for any other mechanism for controlling fishing effort; others are specific to the enterprise quota system. Among the more important imperatives for controlling fishing effort under any system are the following:

(a) A knowledge of the resource sufficient to permit the establishment of an annual TAC at a biologically safe level

(b) Sufficient knowledge to establish an economic harvesting level

(c) A control and surveillance capability sufficient to ensure that whatever harvesting level is authorized will be respected

(d) Adequate research and administrative resources to ensure continuing of required knowledge

(e) A competent and timely data base for all these purposes

In addition to the above, there are other imperatives that are specific to an individual enterprise quota system. Among the more important such imperatives are:

(a) Good historical data on the catch and on the costs and earnings of the existing fishing vessels, including their replacement costs

(b) A system for the establishment of the size of the individual quotas that is seen to be fair

(c) A long-term commitment to the system by the management authority, to provide some sense of permanency for enterprise owners so that they may make realistic investment decisions

(d) A practical method for trading quotas or parts of quotas, sufficiently well enunciated so that the participants understand its application and operation

(e) Acceptance of the system by the owners of the enterprise after proper consultations

(f) Formal group organization of the enterprises involved if these numbers are more than a dozen

(g) A set of guidelines that will protect the interest of the founder group and specify clearly the conditions for admitting new entrants

(h) Some central form of catch-marketing: either by an auction, a cooperative or a State-controlled marketing agency; and, last but not least

(i) A better than average local fisheries manager who is committed to making the system work and enjoys the confidence of the fishermen and the support of senior management

I think it will be obvious from the above list of imperatives - and likely I have missed some - why individual enterprise quotas have not been more popular, given the benefits that a properly constructed system could yield not only to the enterprise owners but to the State as well.

4. THE CANADIAN EXPERIENCE

Enterprise quotas as a tool of fisheries management have been in existence in Canada for more than a decade. Lake Winnipeg fishermen have had quotas for the main species fished since 1972 and the vessels participating in the seal hunt off Newfoundland were also placed on quotas about the same time. There are at least nine fisheries now operating under an individual enterprise - quota system on both coasts and at least one large lake.

The most recent enterprise-quota system was established in the largest Canadian offshore fishery: the Atlantic wet-fish trawler fishery for groundfish. The fleet comprises nearly 150 vessels, 100 ft in length (LOA), catching over 400,000 tons of fish in 1981 and employing over 2,500 fishermen. About 80 percent of the vessels are owned by four vertically integrated fish-processing companies; the remaining vessels are owned by smaller processing companies and individuals.

The enterprise-quota system for that fleet was developed in 1981 and established on a trial basis in 1982. The experiment is being extended into 1983 at the request of the participants. Consultations with the principal fleet owners began in January and did not conclude until the end of December when all participants had agreed to try enterprise quotas on an experimental basis for one year. During 1981, several studies were undertaken by the Government and the fishing companies. The studies included the construction of a simulated computer model of the fleet. This was required to demonstrate more accurately than was done before that the current fleet had considerable excess capacity, given the resources that the government was prepared to allocate to this fleet. During the consultations with fleet owners, it was agreed that the quota system, if established, would include a provision for trading quantities of fish within the quotas.

This was the first time in Canada that nearly all the imperatives listed in Section 3 above were fulfilled. It could be argued that the first imperative, which demands a long-term commitment, was hot honoured. This, however, was at the request of the participants; the government was prepared to make the long-term commitment. It is also true that there is no central marketing, because the fleet is so largely owned by vertically integrated companies. Normally this would increase the amount of cheating and make policing very difficult. In the case of the larger trawler fleet, this is less serious because the vessels land their catch at major processing plants where fisheries inspectors are located, making the policing of the quotas much easier.

As to its success, it is too early to judge. It is interesting to note that, for the first time, the fleet owners chose not to catch the entire northern cod quota during the winter but to retain a portion which was fished in the following November and December because it made more economic sense to do so. The fleet caught more fish than in the previous year even though some vessels were tied up. It will obviously take several years to establish the success or failure of the system, although some observers are ready to write it off because it did not yield all the anticipated long-term benefits in the first year!

In spite of the fact that none of the other individual enterprise-quota schemes met all or most of the imperatives, they all represent an improvement over previous management systems and none has been abandoned. None of the quota arrangements contained provisions for trading quotas: an element which is central to the long-term success of the system. Only two included central marketing and one of these only for four years. The cheating problem in the latter case began when central marketing crumbled. Nevertheless, this particular scheme, which involved the Bay of Fundy purse-seining herring fishery, is still functioning. In a recent conversation by the author with a senior captain of that fleet, it became obvious that, with some encouragement from the management authority, central marketing could be restored and quota trading introduced into the management system. In a separate paper, prepared in 1981, I have described the Bay of Fundy quota system and how it operated from 1976 to 1980.

5. CONCLUSIONS

The individual enterprise-quota system is better understood in theory than in practice. As one fisherman on the Pacific Coast put it: "It is better for economists than for the fishermen". For some fisheries he is correct, while for others he is wrong. In some respects it appears complex, difficult to establish and even more difficult to police. Yet, if properly constructed, accepted by the fishermen and adequately supported by the management authority, it can be an ideal system requiring the minimum of regulations and being self-policing. To achieve this, however, the imperatives listed in Section 3 above must be fulfilled.

Individual enterprise quotas represent one approach to the control of fishing effort and the removal of the incentive to over-invest. It is not the only one and not necessarily the best one for all fisheries. It requires a very sophisticated fishery-management establishment and well organized, intelligent and well educated fishermen if it is to succeed. As the system has been in operation on such a limited basis and for such a short time, there is much to be learned before it will be as widely accepted as some other systems. It is only then that we can begin to judge its merits.

FINANCIAL MEASURES TO REGULATE EFFORT

by

B.S. Brochmann
Director of Planning
Ministry of Fisheries
Oslo, Norway

Introduction

According to background documents received from FAO, the World Conference on Fisheries Management and Development which FAO is planning should draw special attention to the opportunities now available, through management, to improve the net social, economic and food-supply benefits from the fisheries. I shall concentrate on financial measures to "improve the net (economic) benefits from the fisheries". I shall not say very much about improving social welfare and the food supply. In my opinion, first priority must be given to the economic benefits. This is obvious; in the long-run you can hardly make an unprofitable industry responsible for the food supply or social welfare.

I am going to speak about theory and practice. First, I shall give a brief summary of what measures economic theory recommends when the objective is to maximize the net profit of a fishery. Then I shall compare how practice corresponds with theory. Nor surprisingly, we observe an obvious distance between the two. Then I ask: What is the reason? Is something wrong with the theory? Or do political circumstances perhaps make it impossible to implement the recommended measures? Or perhaps the paramount objective of policy is not to attain maximum profit, and hence the recommended measures are irrelevant? In this short paper, however, I manage only to touch the surface of these complicated matters.

The theory as applied to a single stock exploited by one nation

The simple supposition is that only fishermen from one nation are harvesting the fish stock in question. In order to gain maximum net profit from the fishery, the economic theory of fishing recommends that fishing effort should be reduced as compared with the free-access situation. This reduction can be achieved either by imposing a tax on fishing, by implementing a licence scheme or by combining these two measures. There exists an optimum tax level and an optimum number of licences (or licensed catch-capacity) which, in the long-run, will maximize net profit (net profit = surplus left when all capital and running costs have been paid for, including a normal remuneration for the fishermen concerned).

The reason for the recommended reduction in fishing effort is that such a reduction will lead to a restoration of the resource stocks. Here it must be added that, according to the pure theory, the advantage of having a larger stock is not that it can sustain a higher catch level. Instead, the economic advantage of a large stock is that the greater the stock the more abundant the fish and the lower the cost per ton of fish caught. Thus profitability per vessel is increased. A net profit, a rent, can be achieved.

If reduced participation is achieved through imposing a tax on fishing, the net profit which emerges as the stock is allowed to increase accrues society, and the fishing sector experiences normal returns (normal as compared with those obtained elsewhere in society). If the reduced effort is promoted through licensing, should the licences be issued free of charge or should they be paid for? Economic theory does not recommend free licences. Instead, the recommendation is to sell off or to auction licences for an optimum level of fishing effort (capacity). In this case too, the net profit or rent of the fishery will accrue to the treasury and the fleet will gain normal returns.

Practice: A single stock - One nation

In practice, a tax on fishing or a system of auctioning fishing licences is exceptional. Instead, if the authorities intervene, they most likely will behave contrary to the mentioned recommendation and give economic support to the fishing industry. The argument very often is the low level of income which typically is found in remote areas heavily dependent on the fisheries. The immediate impact of such a subsidy scheme will be a higher level of income among the fishermen. The effect of a higher level of income will probably be reduced migration from these areas and increased participation in the fishery involved, as compared with what it would have been without this kind of intervention. Together with ongoing technological progress, this may in the long run result in over-exploitation of the stock(s) being fished. If this happens, the catch overall will be reduced and subsidization will have to be increased in order to compensate for the drop in catch.

Increased support in this way prevents the adjustment in the level of participation which would otherwise take place when catch per vessel drops. Since high fishing effort will thus be perpetuated, the stock may very soon be depleted and the need for support of the fishermen affected will be further increased. This in short is how a crisis in the fishing industry may arise. In fact, the sequence described above has occurred several times in more than one country.

If a limited-licence programme is introduced in response to increased catch capacity and fear of over-exploitation, the licences are normally issued free of charge to the holders. Management of the licensing system, however, will be difficult to carry out. Since existing fishing effort proved to be too high, a licence scheme which gives the vessels previously participating the right to continue fishing (the normal case) and only newcomers are refused entry, will not be sufficient to restore the stock, especially if technological progress goes on at the same time. Sooner or later, even a limited number of licensed vessels will be able to over-fish the stock.

Alternatively, the crisis may be postponed by giving licences to only a few of the active vessels or by means of a buy-back programme. As the stock is restored, the privileged licence-holders may gain a profit which is excessive in relation to that obtainable in a competitive market. There will be pressure from "outside" fishermen seeking to obtain licences. At the same time, the licence-holders themselves will apply for permission to increase the capacity of their vessels. The rest of the society may well consider the generally high income level among the licence holders to be unjust. The investment level in the regulated fishing fleet will most probably be excessive, due to the windfall profits earned, and catching capacity may be expected steadily to increase despite the restricted licensing programme. Over time, the stock will again be threatened by over-fishing. This, together with increased capital and running costs, is likely to eliminate undue profits. It may be of some comfort that the handling of a licence scheme will be easier when the profit of a fishery has faded away.

The theory: A single stock exploited by two nations

When analysing this case, we must distinguish between two types of situations: one when the two countries are cooperating and one when they are not.

Suppose the objective is to maximize profitability. If the two countries are not cooperating, it will be pointless for one country to reduce the effort of its fleet in order to increase stock abundance. Increased abundance may in such cases only lead to increased participation and a higher fishing effort by the other country (presupposing free access). In due course, the previous low fish density will be re-established.

Let us assume that one of these countries, country No. 1, has a very high cost level as compared with that of No. 2. Both countries practice free access to the fishery. When the stock(s) is/are so reduced that fishermen from country No. 1 finding the operation unprofitable must retire from the fishery, the average fisherman from country No. 2 may still find his level of earnings quite satisfactory and continue to expend effort until his net profit too fades.

If the two countries cooperate, however, they will have to agree upon the establishment and sharing of a total quota (TAC) for the stock(s). On way basis should the TAC be fixed? It is well known that fishery biologists have advocated a management policy that would provide a maximum

sustainable yield (MSY) in physical terms, whereas economists argue for a stock level that would maximize the profitability of the fishing activity (MSP). Normally the stock level which corresponds to MSP is larger than the one corresponding to MSY. In practice, the concepts of MSY and MSP will be of minor interest for many years to come. Most stocks in the North-East Atlantic waters are over-exploited and have to be restored. The optimum growth rate of the stocks is, however, not a question of fishery biology: it has to be decided on the basis of economic and social considerations.

Two countries with different cost levels or social systems will not easily agree upon what should be the optimum growth rate for the stocks they share. On the other hand, obtaining some growth is far better than to continue the anarchy hitherto prevailing, which led to the current state over-exploitation. Because of this, even countries with very different economic systems tend to accept the recommendations of fishery biologists as a neutral and common platform and a reasonable basis for the fixing of TACs. Assume that country No. 1 has got its share of the TAC, i.e. its national quota. Suppose in addition that, with free access, the catch is expected to exceed this quota. The authorities will then have to regulate the fishing effort of the national fleet. Several instruments are at hand:

(a) Stop systems: fishing operations may be halted when the quota is exhausted or the national quota may be divided into vessel (or vessel-group) quotas which means that each vessel is laid up when its quota is taken.

(b) Gear restrictions: for instance, a maximum number of nets being permitted per vessel. The economic impact of gear restrictions normally is reduced efficiency of the factors of productions involved.

(c) Licensing (limited entry): licences being issued free (which may give licence-holders excessive profits) or being distributed by auction.

(d) A tax on fishing: the tax or royalty being levied so that participation is restricted to the effort required to harvest the national quota efficiently. The impact of such a tax is exactly the same as that achieved through auctioning the appropriate numbers of licences.

Practice: A single stock exploited by two or more countries

Since the establishment of 200-mile economic zones in the North-East Atlantic, the coastal States concerned have developed fruitful ways of cooperating in the management of fishery resources. All important fish stocks in these waters are now regulated by TACs and, year after year, the participating countries have managed to come to an agreement about the level and sharing of TACs. In my opinion, this bears witness to responsible, disciplined policies.

As expected, however, none of these countries impose a tax or other kind of charge on fishing as a means of obtaining an appropriate level of fishing effort. In fact, the tendency is rather for the authorities to behave contrary to theoretical directives: the fishery sector in many countries actually is being subsidized. The most common measure has been to subsidize investment. In recent years also, measures to lower fuel prices or to provide financial compensation for the high fuel prices have been implemented in some countries. In Norway, the prices fishermen obtain for fish landed are heavily subsidized by the government. Not surprisingly, these measures have stimulated investment in the fishery sector. The present level of investment is at least higher than what would have been the case without these and other subsidies.

The Norwegian case

To get an understanding of why the potential fishing effort in the Norwegian fishing fleet is so high that national regulations are necessary, a short historial introduction is needed.

The fishing fleet in Norway receives governmental economic support and every year negotiations to determine the extent of this support take place between the authorities and the Fishermen's Association. Originally, the basic objective of economic support for the fisheries was to improve efficiency and profitability in the fishing industry as a whole, so that this industry could develop

independence of subsidization by the government. Measures designed to improve profitability were carried out but most of the support went to raise fishermen's income, e.g. through price subsidies on raw fish and reductions in the price of gear and bait.

This policy has been successful enough from the standpoint of fishermen's income enhancement. Average earnings per man/year in the Norwegian fishing fleet (vessels of 40 ft and above) as compared with wage levels in the industrial sector over the past decade are shown in Figure 1. With reference to the trend indicated, one must bear in mind that the income level in the industrial sector in Norway is relatively high, which makes the result achieved for fishermen even more impressive. On the other hand, to achieve this seemingly good result, the amount of subsidization had to be steadily increased, as shown in Figure 2.

In the early years, increased fishing effort (resulting in large part of the subsidy scheme) led to an almost corresponding increase in catch which in turn caused increased activity in the processing industry and in the diversified activities deriving from fishing and processing. The policy thus seemed successful. In the long run, however, the growth in the quantity of factors of production (gear, fuel, capital) could not produce a proportional growth in the catch. One after another, the available fish stocks became fully utilized. In some cases, it could be observed that an increase in the use of production factors in fishing was followed by a reduction in catch, indicating over-exploitation of the stock(s) involved.

In order to avoid such a result, several licence schemes were introduced at the beginning of the 1970s. The need to regulate fishing effort, of course, might well have arisen even without income support. There is no doubt, however, that increased raw-fish prices and lowered running costs stimulated investment and increased fishing effort. When the system of quotas was implemented, about 1976-77, excess capacity in relation to quotas became a prominent feature of the Norwegian fishing fleet.

The combination of (a) growth in the quantity of production factors involved in fishing and (b) stagnation or even a drop in catches, naturally has led to severe economic problems in the fisheries. The increased financial support for the fishing industry (Figure 2) may be understood against this background. Another explanation for the increasing deficit is that, after 1975, Norway has experienced a general loss of economic competitiveness, partly as a result of the oil-revenues from the North Sea. This development has squeezed profit margins in all Norwegian exporting sectors, including the fishing industry.

Were it not for governmental income support to the fishery sector, over-capacity in the Norwegian fishing fleet would not have occurred - at least it would not have been a permanent feature. This over-capacity necessitates the imposition of controls to restrict the catch. In the cod fisheries, there is free entry for coastal vessels but participating vessels are subject to gear restrictions and stop-periods. The cod catch of the deep-sea trawlers is regulated by a separate trawler-quota which in turn is divided among the trawlers. The over-capacity which makes these regulations necessary is an important reason for the present unhealthy economic situation in the cod fisheries. Even a fishing fleet with a capacity reasonably in balance with the cod quota would hardly be able to cover all costs, including normal remuneration for fishermen, because of the generally high cost and income levels prevailing in Norway.

Turning to the purse-seine fleet, fishing mainly for capelin, mackerel, sprat, etc., for reduction to fish meal and oil, we discover there also an evident excess of capacity. Fishing effort is regulated by means of individual vessel quotas, fixed in such a way that in the aggregate they equal the national quota. Only purse-seiners holding a licence get a catch quota. Owing to the excess capacity, if economic support were withdrawn from this fleet, losses would surely follow. The vessels, nevertheless, are so efficient that a purse-seining fleet, with capacity adjusted to match the quotas, would ensure the ship owners a profit in normal cases, despite high cost and income levels in Norway. Here we have an interesting example of a situation where it is possible to obtain a resource rent, i.e. a net surplus from a fishery, by imposing a licence fee or a levy on the catch, and still assure fishermen and shipowners of a "normal" level of remuneration.

Conclusions

The main conclusions so far are threefold:

Firstly, the licence schemes must be maintained, not for fear of over-exploitation, but chiefly to restrict investments in new vessels and overall participation in a fishery. A licence scheme thus works to counteract the expansive effects of State income support.

Secondly, in the Norwegian case, it is not necessary to impose a tax on a fishery to get rid of excess capacity. It is sufficient to withdraw support programmes.

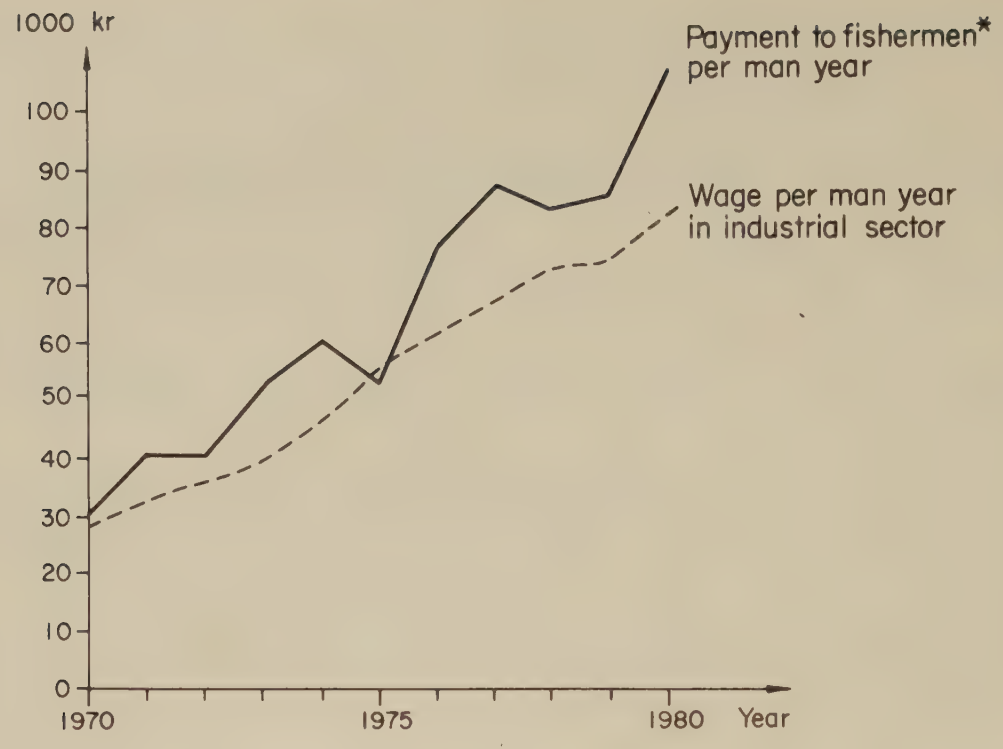
My third conclusion is this: if, e.g. for political reasons, it is not possible to follow the advice which economic theory offers, namely to impose a tax on fishing, the opposite at least should be avoided. In the long run the latter will have severe and detrimental effects, both in economic and biological terms.

If the government intends to support sparsely populated areas, in order to raise income levels to prevent out-migration or for general social reasons, the appropriate measure would be economic support either to promote infrastructure (communications, education, public services, etc.) or to stimulate economic activity in different sectors of trade and industry - including fisheries, but on a non-discriminative basis. One should not appoir' one single industry (i.e. the fisheries) to bear the burden of achieving societal goals (for instance, to maintain a pattern of settlement). The long-term impact of such a policy would probably be to ensure the fishing industry becoming a permanent deficit sector. That would in turn render it useless as a provider of secure and well-paid workplaces in the fishery-dependent areas.

My arguments may be said to be only of theoretical interest and of little relevance as guidance for a government eager to create new workplaces in remote coastal regions with low income level and a high rate of unemployment. If the national quota for a fish stock is far from being exhausted, because of low or zero economic return in the fishery, would it then not be wise to provide a price subsidy on raw fish if this would restore profitability and create economic activity? My answer is yes, but only on the condition that other industries and trades in these areas get the same support.

The possibility of "renting" the surplus quota to other countries should also be taken into consideration. The income of such a sale may be used to develop trade and industry in the coastal regions on a broad and differentiated basis.

If profitability is not high enough to ensure that the national quota is caught, even though the fish stock is healthy, the cause is to be found either in general high cost and income levels in the economy or in inadequate efficiency of the fishing fleet and/or the processing industry. Given the first set of conditions, nothing needs to be done, as the high income level probably reflects a high employment rate. In the case of inadequate efficiency, one should rather do something about the inefficiency instead of offering financial support to an inefficient industry. The Norwegian experience tells us that combining financial support for a specific sector and achieving increased efficiency in that particular sector is a very difficult performance.



* On vessels of 40 ft and above

Figure 1 Wage in the Industrial Sector and payment in the fishing fleet (vessels of 40 ft and above, at sea for 30 weeks or more per year) - average per man/year

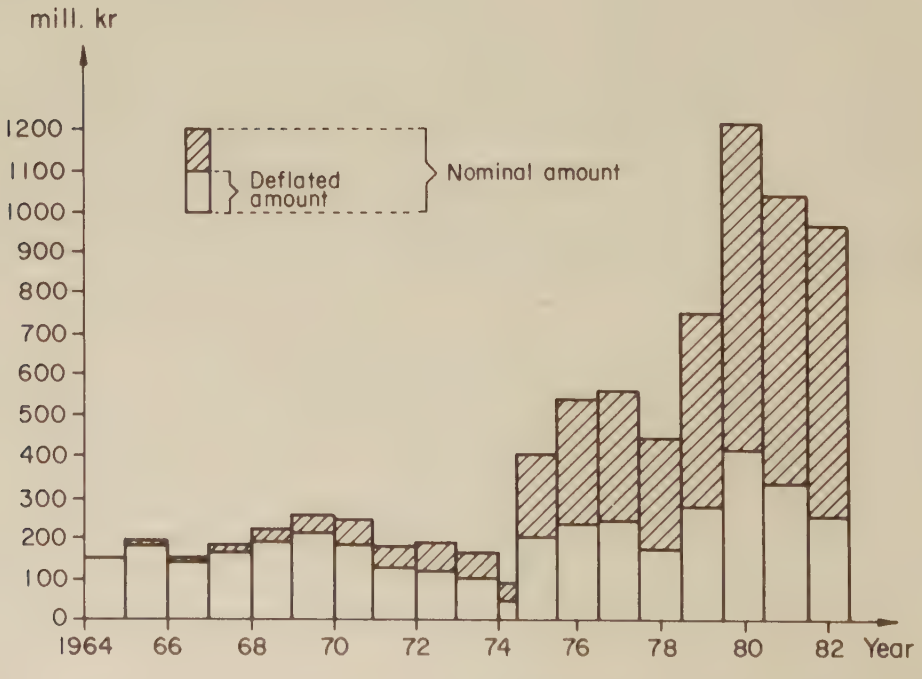


Figure 2 Governmental support to the Norwegian fishing fleet - nominal and deflated amount

AN ALTERNATIVE TO EQUILIBRIUM THEORY FOR MANAGEMENT OF FISHERIES

by

J.F. Caddy
Marine Resources Service
FAO Fisheries Department
Rome, Italy

INTRODUCTION

The idea that a state of equilibrium can be reached between the harvestable production from a given fish stock and the level of fishing effort or fishing mortality exerted on it has played a key role in the development of the two main branches of the theory of fish stock assessment; namely, the analytical or Beverton and Holt (1959) approach and the global or surplus production modelling approach.

In the first of these schools of thought, the response of a stock to fishing is examined in detail, growth and mortality parameters being estimated by detailed observation of the stock over a short period of time, and from this the presumed long-term effects of a change in fishing strategy (size limits, fishing intensity) calculated; the assumption being made that the fishery system operates as a closed chemostat, within which any change in the variables controlled by man will eventually result in a reproducible effect (a "sustained" yield) after enough time has elapsed. Surplus production models treat the population as a black box, in which a given level of effort exerted at any point in time eventually results in the same equilibrium level of production being sustained. Similar equilibrium assumptions also underly much of the body of theory developed in the field of fisheries economics, which has been widely used for guiding investment decisions in fisheries.

Although the steady-state concept is essential to a preliminary understanding of the factors that govern the yield attainable from a fishery, unfortunately its widespread uncritical use tends to obscure the fact that certain sequences of events tend to take place in the development of a fishery that are not easily explained in terms of an equilibrium state. Such sequences may be due either to the long term effects of past levels of fishing intensity or even to the rate of application of fishing intensity, or they may be due to changes in the environment or even to a combination of both types of effects. What seems clear, however, and has serious implications for the development process in fisheries, is that the repercussions of a particular investment decision may continue to be felt in the fishery for many years after its time of application and that this response time of the system is likely to be longer than most fishery administrators expect. The existence of such feedback mechanisms is becoming even more relevant nowadays that the rate of build up of fishing effort in new fisheries is far too fast to allow the system to provide the necessary feedback for correct management decisions in the future. Some of the implications of making investment decisions without allowing for feedback of information to the fishery manager are explored in this paper, and a number of management guidelines suggested.

ADJUSTING FOR NON-EQULIBRIUM SITUATIONS IN FISHERIES MODELS

The difficulties of fitting production models to essentially non-equilibrium data on catch and effort, where fishing effort is increasing as rapidly as in some of the fisheries shown in Table 1, has preoccupied fisheries scientists for the last two decades. Several rule of thumb methods exist, which adjust the data points to allow for departures from a supposed equilibrium condition before drawing the kind of yield curve shown in Fig. 1. These methods of adjustment essentially use previous years' data to adjust the present year's data. The basis for this adjustment is that the abundance, and hence catch, for a given effort in the present year, is influenced by the past fishing intensity over the number of years that the older fish in the catch have been in the fishery. We may, however, look at this procedure in the reverse sense, namely that "massaging" the data to make it fit some supposed set of equilibrium conditions may be removing vital information on the sequence of events that is needed by managers of the fishery.

Table 1 Summary for a selection of fisheries of the time taken to MSY from various bench marks in fisheries development

Species, area and author/publication	MSY (last year reached)	Years to first MSY from start of fishery (or from 10% MSY)	Years to first MSY from 25% MSY	Years to first MSY from 50% MSY
Atlantic menhaden USA: Atlantic (Klima, 1976)	620,000 t (1954-55)	?	?	?
Gulf menhaden USA: Gulf of Mexico (Klima, 1976)	478,000 t (1962)	14-15	12-13	6-7
Hake (Merluccius spp.) South Africa (Newman et al., 1976)	150,000 t (1964-65)	?	?	before 1955 i.e. 10+
Redfish Div. 3P ICNAF (N.W. Canada) (Parsons & Parsons, 1975)	23,000 t (1966-67)	?	?	3-4
Spiny lobster Munroe Co. Florida, USA (Stevenson, 1981)	3,000 t (1970)	?	14-15	5-6
Penaeid shrimp (all species) Nicaragua (Stevenson, 1981)	3,500 t (1968-69)	?	5	4
Snapper (Lutjanus purpureus) N. & N.E. Brazil (Stevenson, 1981)	5,800 t (1972)	?	6-7	6-7
Spiny lobsters (P. argus + P. laevicauda) N. Brazil (Stevenson, 1981)	8,500 t (1968-69)	?	?	2
Stone crab (Menippe mercenaria Florida, USA (Stevenson, 1981)	645 t (claws)	?	13	7
Shrimp (Pandalus borealis) Iceland (Skulladottir, 1979)	600 t	?	?	1-2
Mackerels (Tracharus spp.) N. sub-tropical, W. Africa (Troadec & Garcia, 1980)	190,000 t (1969-70)	5 ?	3	2

Figure 1 illustrates the course of events in a fishery whose "equilibrium" yield is given by the dashed line and the 'raw' data points by circles. Because effort is increasing rapidly in the early stages of development (and rarely, if ever, remains constant anyway), the fishery during the early stages is always exploiting bigger stocks than would be present if that level of effort had been constant for several years. As a result, the 'sustainable' yield is always overestimated if there is not time enough during the early stages for the yield to fall towards its equilibrium value. Erroneous feedback as to the potential yield thus continues to fuel the over-investment situation discussed later. Only after a number of years at a fixed effort level (years 5-7 in Fig. 1) does the yield tend towards the equilibrium line (year 7 in Fig. 1), and we may note that this equilibrium yield is only going to stay constant if the environment remains unchanged.

Vice versa, as effort decreases the actual yield is less than the equilibrium yield, since it takes time to increase the biomass by growth to a higher level corresponding to the now lower effort level. You will find that the close to circular trajectory of effort and yield in the figure is fairly typical and corresponds conceptually to that discussed later (Fig. 5), for a predator-prey system. Implicit in Fig. 5 is the fact that both predator-prey systems, and a special subset, namely fisheries systems, are dynamic and have a tendancy to follow characteristic sequences of events such that, although we can define an equilibrium point X in Fig. 1 which is one of the 'best' targets for management, this point is rarely attained since the fleets and the resource are each reacting to the other in a linked predator-prey system.

Perhaps the conclusion we should draw from this is that what is random 'noise' with respect to one model may actually represent the information content under a different conceptual framework.

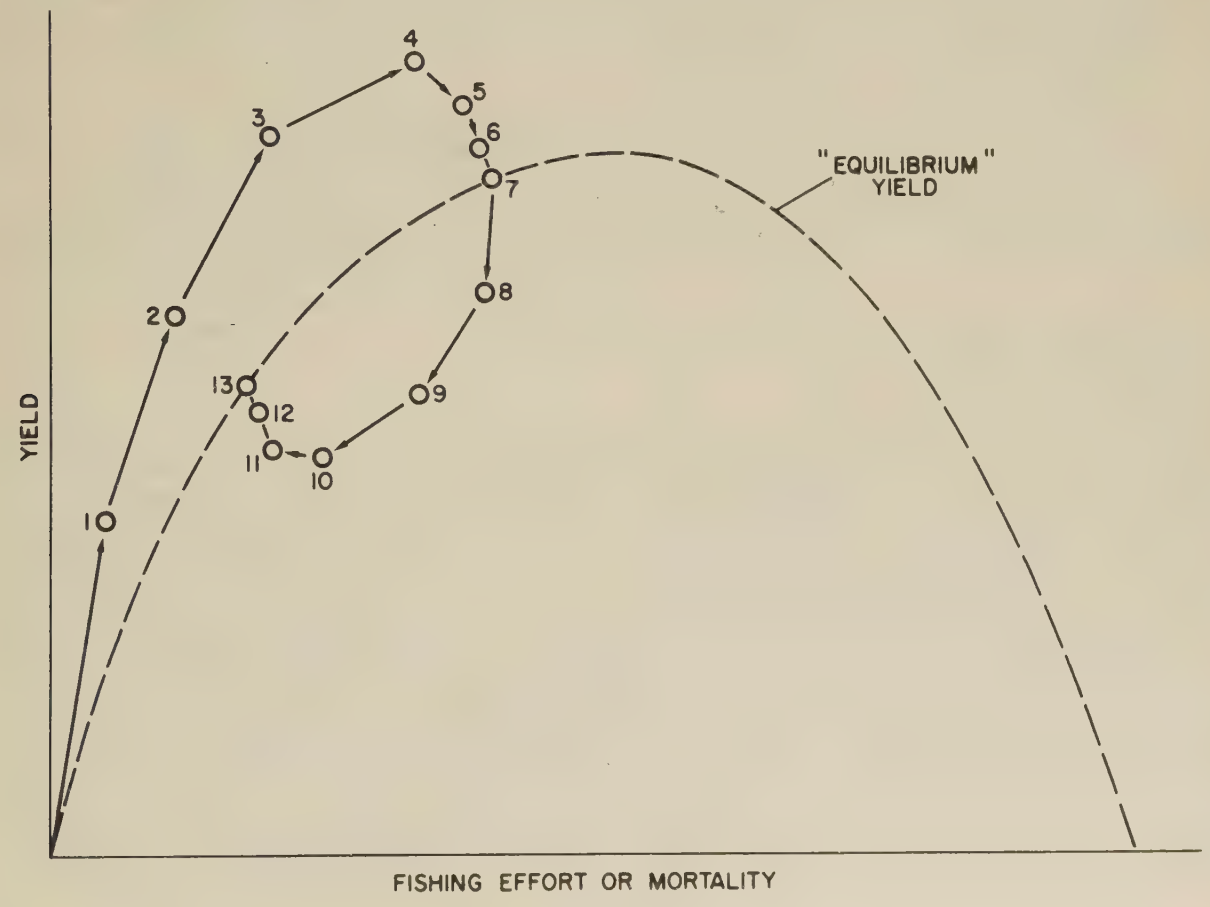


Figure 1 Sequence of events in the early expansion phase of a fishery (years 1-7), showing how annual yield exceeds the equilibrium level unless effort level is held constant for several years. Conversely, if effort decreases, yield drops below the equilibrium line until held constant for several years.

HOW LONG TO GET TO MSY?

Looking at Table 1 we see a range of estimates made from various production models in the literature which show that the time taken to reach MSY has generally decreased for industrial fisheries since the 1960s. In few cases do we have good information on the yields from early years of a fishery, and the time to MSY has been calculated from the year that 50 percent MSY was attained; this appears to have dropped significantly from a decade or so in the 1960s to two years by the 1970s and corresponds to a supposed time from the start of development to MSY of probably rather more than twice this, i.e. roughly 4-5 years to MSY by the 1970s. This is around or less than the life span of many of the species harvested. The high rate of mobilization of effort and investment possible nowadays appears to be responsible here. What is most striking to a biologist about this is that, starting from scratch, it is now possible to more than double the natural death rate of a population over a period of some 3-5 years. Far from being appropriate to describe this in terms of equilibrium theory, we need to look at the ecological impact of this type of fishery from the same perspective that we would use for other "catastrophic" phenomena like earthquakes, tidal waves, etc. This theme is developed further later on, but it certainly appears that the chances for a realistic adjustment of data from the early years of such rapidly incrementing fishing effort are rather poor. Some other models for management appear to be urgently required.

RESPONSE TIMES IN INVESTMENT AND MANAGEMENT

Fisheries systems may perhaps be compared to the behaviour of a badly adjusted thermostat in that the time lag from the signal to the response, particularly when low catch rates signal that management is appropriate, is much longer than the time of response of the fleet to improved levels of abundance. A hypothetical example of the sequence of decisions is shown in Fig. 2 which illustrates that there are two options:

(a) Improve response time of management

or, (b) Slow down rate of entry of new vessels into the fishery.

It is the author's opinion that the latter is the more feasible alternative and this question is explored further in later sections. A real-life example of how the slow response time of the management systems was responsible for the demise of an important fish stock is given in Table 2.

THE BIOLOGICAL BASES FOR THE NON-EQUILIBRIUM SITUATION IN FISHERIES

The major source of energy that drives fisheries systems comes from fixation of carbon dioxide into organic compounds by marine plants and this process tends to show peak production in rather localized regions, such as in areas of high vertical mixing of water masses; for example, areas of upwelling, the continental shelves of high and low latitudes and further offshore along horizontal and vertical boundaries between ocean current systems. Highly productive areas nearer inshore are estuaries, lagoons, salt marshes, seaweed beds and mangrove swamps. Despite the generally low productivity of clear water tropical areas, coral reefs also act as centres for concentration and elaboration of organic production. Dispersal of organic material in the form of organic detritus, plankton, fish and invertebrate biomass from these centres of production goes on in space and time from the original date and location of organic synthesis. This occurs both passively by means of eddies and currents, and more actively by means of migration of living organisms. All of the time the synthesized organic material forming the bodies of plants and animals moves upwards in the food web and loses roughly nine-tenths of its biomass and chemical energy at each step in the form of metabolic heat, work, excreta (soluble organics) and detritus; some of the latter two categories being cycled back into the food web by means of marine bacteria and other unicellular organisms, scavengers and detritivores (e.g. filter feeders).

Table 2 Management history record (from Saetersdal, 1980)

Year	Stock diagnosis by Liaison Committee	Management objective	Advice given	Measures agreed	Regulations enforced
1965	Large total stock decline, but natural cause assumed. Effect of fishing on juveniles uncertain		Exploitation still at level where no benefit for total landings expected by any regulatory measure		
1968				A number of delegations at NEAFC expresses concern about the state of the stock	
1969			A special meeting organized by ICES to assess the stock		
1970	Stock in poor state due to: a) recruitment failure, b) increased rate of exploitation on adult stock and larger immature herring	Increase the stock and long-term future fishery possibilities endangering prospects for future reproduction)	Reduce mortality rate on immature herring and avoid further increase in fishing rate on adult stock		
1971					Restrictions on fishing for immatures
1972	No signs of stock recovery. Reiterates 1971 statement		Advice from 1970 repeated		
1973	Stock still in critical state and shows no signs of improvement at all				
1975	Stock collapse fully confirmed. Spawning stock probably too		Total ban on all fishing	Ban on commercial fishing in 1976	
1977	Some indications of recovery, but spawning stock still at a very low level		Total ban continued in 1977		

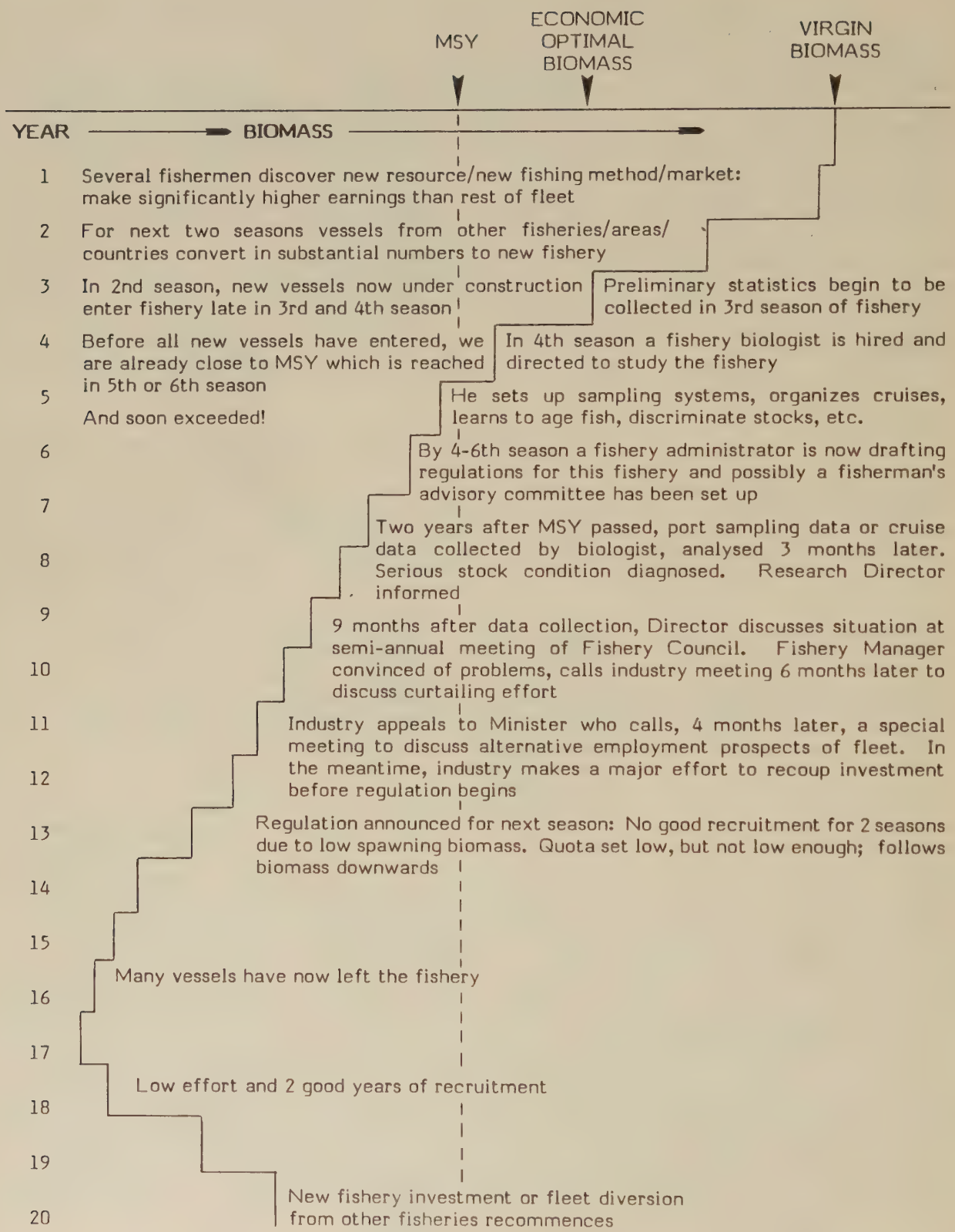

MSY
ECONOMIC OPTIMAL BIOMASS
VIRGIN BIOMASS
YEAR
BIOMASS
1 Several fishermen discover new resource/new fishing method/market: make significantly higher earnings than rest of fleet
2 For next two seasons vessels from other fisheries/areas/ countries convert in substantial numbers to new fishery
3 In 2nd season, new vessels now under construction enter fishery late in 3rd and 4th season
Preliminary statistics begin to be collected in 3rd season of fishery
4 Before all new vessels have entered, we are already close to MSY which is reached in 5th or 6th season
In 4th season a fishery biologist is hired and directed to study the fishery
5 And soon exceeded!
He sets up sampling systems, organizes cruises, learns to age fish, discriminate stocks, etc.
6 By 4-6th season a fishery administrator is now drafting regulations for this fishery and possibly a fisherman's advisory committee has been set up
7
Two years after MSY passed, port sampling data or cruise data collected by biologist, analysed 3 months later. Serious stock condition diagnosed. Research Director informed
8
9 months after data collection, Director discusses situation at semi-annual meeting of Fishery Council. Fishery Manager convinced of problems, calls industry meeting 6 months later to discuss curtailing effort
9
10
Industry appeals to Minister who calls, 4 months later, a special meeting to discuss alternative employment prospects of fleet. In the meantime, industry makes a major effort to recoup investment before regulation begins
11
12
Regulation announced for next season: No good recruitment for 2 seasons due to low spawning biomass. Quota set low, but not low enough; follows biomass downwards
13
14
15
Many vessels have now left the fishery
16
17
Low effort and 2 good years of recruitment
18
19
New fishery investment or fleet diversion from other fisheries recommences
20

Figure 2 The sequence of decision processes in development and management of a fishery - A hypothetical example

Transport processes must largely account for the generally lower productivity and standing stocks in central oceanic areas and at greater depths, distant from the main centres of production. This is especially true for deeper waters in the tropics, where stable thermoclines may restrict high production to near-shore areas. Peak production is also rather restricted in time, especially in regions of upwelling and estuaries, in north and south temperate phytoplankton blooms, and seaweed and eel grass beds. This means that the herbivores feeding on plant material and the primary carnivores feeding on them tend to be often (but not always) small, short-lived (annual species) with big population blooms and crashes on a seasonal basis. This is also true in the tropics and sub-tropics, in those areas where seasonal monsoons drive upwelling zones; for example, in the northern Arabian Sea and off Peru, but not so obvious in other tropical areas where low-level production goes on throughout the year.

One way to visualize this process is to view the food web as a dissipation structure (Johnson, 1981), whereby input energy from the sun in chemical form moves up through the food web, losing a large fraction as heat at each stage in the course of work performed by individual organisms in carrying out the various metabolic processes necessary for the maintenance of life. At the same time the value of the individual energy package generally increases, so that a small fraction of the original (low-unit value plant material) becomes high-value fish tissue (e.g. tuna, codfish, etc.), which is energy-rich and preferred for human consumption and usually commands a higher market price.

In placing any natural system along the stability scale from close to equilibrium to wild fluctuations or periodic population crashes, the time scale of production is evidently very important; the flow of energy through a system is unlikely to closely approximate stability if production is seasonal or, even worse, erratic. The chances of managing a system are likely to be improved if there is a relatively continuous stable production and fortunately, even in very seasonal (but regularly fluctuating) systems, higher level organisms have often evolved life history mechanisms to ensure that their production 'evens out' somewhat the seasonal cycle, by seasonal changes in diet at different times of year or during different life history stages or by migration to locate other areas of peak production.

In fact, a whole new group of life history strategies come into play once evolution of multi-age group forms is widespread. Clearly, new strategies for dealing with the "feast and famine" situation caused by seasonal production cycles had to be evolved and, as indicated above, these include active swimming, seasonal migration, separate feeding and spawning areas, 'omnivorous' (more than one food item) feeding and the whole range of associated morphological and behavioural characteristics that make up existing fish species.

The big evolutionary advantage of a longer life span that results when the above problems are solved is that the species can survive instabilities in the environments by adjusting the life span to be roughly equal to the average interval between favourable spawning years, so that a species can survive a poor spawning year that might otherwise be disastrous for localized stocks of an annual species. The life-history mechanisms shown by annual species (e.g. squid, penaeid shrimp) also tend to confirm that the environment that most species inhabit is unstable; compensatory mechanisms include production of many eggs, several separate groups spawning at different times of the year and a fairly wide geographical range for single stock species (e.g. the Pacific squid, Todarodes, Osako and Murata - in press), ensuring repopulation of a stock from the fringes of its range if the centre is wiped out by an unsuccessful spawning, or vice versa.

The existence of multiple age groups is itself then, with or without multiple spawning, a life history adaption that reflects the difficulty of ensuring a species survival in the presence of oscillations or random perturbations in the ecological system and physical environment. These perturbations show up in the form of irregularities in annual recruitment. Recent studies in the North Atlantic (Hennemuth and Avtges, 1982) on long-term recruitment trends in cod and haddock show that the very occasional big year classes play a major part in supporting the fishery; the rest of the time the annual yield would not be sustainable and exceeds current production from recruitment, i.e. heavy reliance is placed on fishing survivors from previous good year classes. For these species, annual landings exceed annual recruitment 70-80 percent of the time; from only 10 percent of the bigger year classes came 24 percent, 33 percent and 37 percent of the total yield for cod, mackerel and haddock, respectively. In such a fishery, it seems likely, and should be investigated, that a series of investment waves have occurred following closely behind good year classes in these fisheries, and this

is hardly likely to prove atypical of what happens in other industrial fisheries elsewhere. Why should we not expect then that such perturbations will affect our fisheries systems in the form of so-called "departures from equilibrium conditions"?

SYSTEM INSTABILITY AND MANAGEMENT

The environment - it goes without saying that fish populations, their abundance and species composition, are very responsive to changes in key environmental variables that are not under control of the Fisheries Manager. In many cases these variables may act on the stocks in a way that are poorly understood, despite a large literature on effects of a range of environmental variables on growth, survival and reproduction success. Convincing proof of this has been provided by recent studies of, for example, the occurrence of fish otoliths in stratified bottom sediments from productive upwelling zones; these show wide fluctuations in abundance and frequent switches in dominant species at specific sites for hundreds and thousands of years prior to human exploitation (e.g. Soutar and Isaacs, 1974).

It has been postulated (Skud, 1982) that the behaviour of dominant and subordinate species in an ecosystem may also be modified in relation to environment, if they change places in relative abundance in the system. For example, if all species when dominant respond favourably to increases in temperature, they may show the opposite reaction when subordinate, since they are now suffering population pressures from the dominant species which is more successful in taking advantage of the changed environment. The point of this observation is that environmental effects, if not understood or taken into account, will in some marine systems make for considerable errors in the yield forecast from a given expenditure of effort in any particular time period (see Figure 3) or, alternatively, will mean that the effective effort resulting from a given TAC will be very variable.

If the "weather effect" on production from a given stock is high (Figure 3), it is possible to set a low quota in "poor" periods of years that greatly exceeds the demonstrated ability of the stock to support it, if the model in question was based on data collected during previous average-to-good years. Such a quota will inevitably accelerate declines in the already reduced stock size. This type of error, resulting from high system variability in combination with poor information on the environment effect (hence erroneous definition of equilibrium conditions), has undoubtedly been one of the main elements contributing to stock declines in managed fisheries. An unwillingness to move too far from a previous years's over-optimistic quota in the face of declining environmental conditions for good recruitment has meant that, although the quota followed annual catches downwards, it was rarely set low enough to arrest the decline. We may also postulate that in some cases, where the downward trend in production was reversed, this was also largely due to an unperceived improvement in environmental conditions.

Although, unfortunately, many fisheries - especially those single and multispecies trawl fisheries of north temperate shelves - may continue from year to year with only moderate landing fluctuations over the short term, there are other fisheries where the system is too variable, the species abundance too transitory or the accuracy of information so low that it becomes impossible to attempt to manage them in a conventional fashion with any good chances of success. A third category of fisheries (and environments) are those that show relatively smooth fluctuations in abundance over a period of years. Fortunately, with these as with the first category, there is a significant degree of autocorrelation in many natural (oceanographically or atmospherically-driven systems) such that, even with a significant difference in population condition and size over, say, 8-12 year intervals, there may be a fairly reasonable similarity in the response of the system to fishing in consecutive years. From the point of view of population-dynamics research, while it may be valid to model the first type of population by means of production (catch effort) models as in Figure 3b, this will be less useful or even misleading for the second two categories (Figure 3a). Here priority should be on yield per recruit studies in association with regular estimates of recruitment. Hindcast equilibrium concepts may be of some value here for long-lived species, but real-time estimates will be needed for short-lived ones. Studies of species interactions and of short term forecasting, using oceanographic parameters, will be necessary in any case.

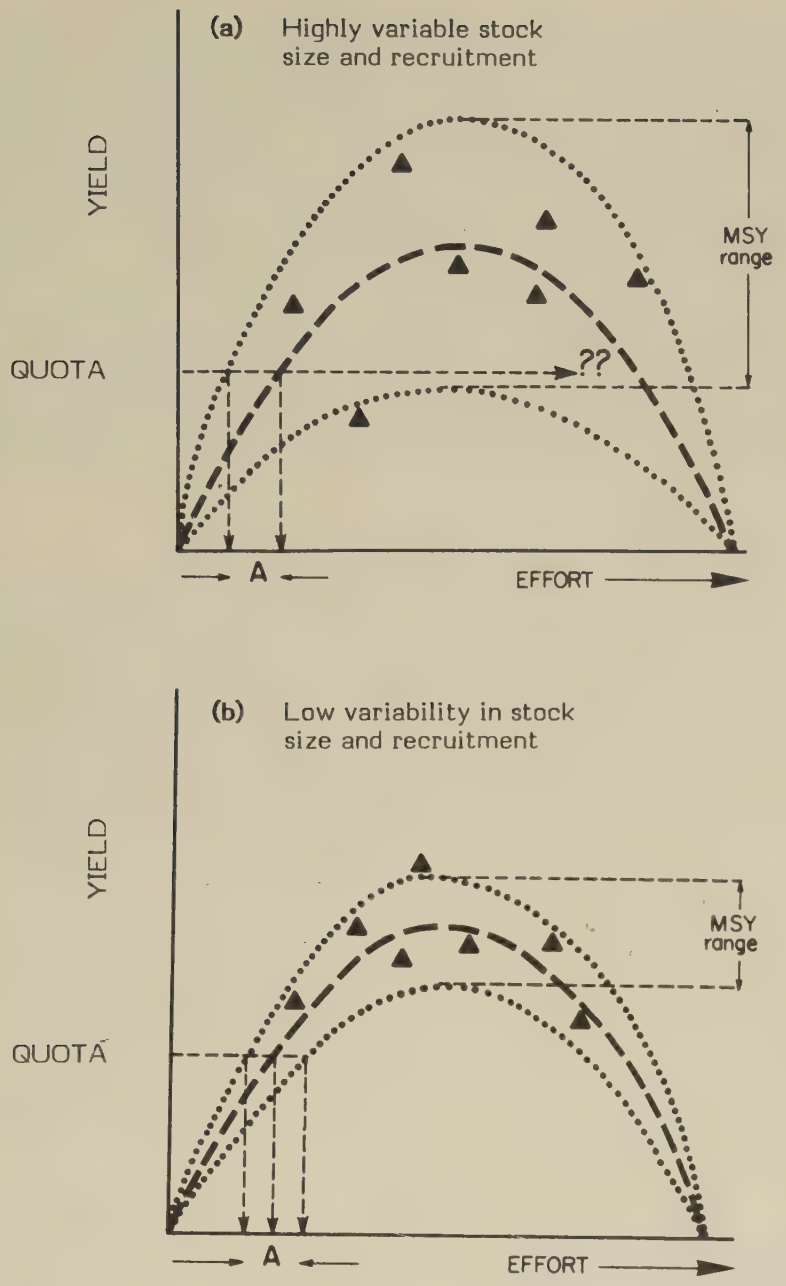


Figure 3

Contrasts production models for two types of population: one (LHS) with highly variable stock size, where recruitment is affected by (e.g.) climate, hydrography or predators, and (RHS) where effects other than effort have little impact.

The dotted lines enclose the points used to fit the relationship in an "envelope" for which the heavy barred line is the mean position and the upper and lower dotted lines 'best' and 'worst' production conditions respectively. The upper diagram shows that in highly variable systems, it is possible to set a low quota based on average conditions that greatly exceed the productive capacity of the system under poor conditions. In this case, the equivalent effort exerted could be very high and destructive without exceeding the quota.

VARIABILITY AND FORECASTING

In the case of highly variable but valuable production systems, there may be good reasons for expending significant resources on the problems of short-term monitoring and correspondingly less value in trying to define a "long-term sustainable yield". In this sense, it is of interest that Japanese fishery science, operating in a zoo-geographical area where the vagaries of a powerful oceanic current, the Kuroshio, are all-important to nearshore fisheries yield, have placed more emphasis on development of methods of short-term prediction of optimal fishing areas and yields and less on defining optimal equilibrium or sustainable yields from the system, which is the main preoccupation for North-East Atlantic fishery science where drastic year-to-year changes in the system may be less intense. Even in the North Atlantic, however, long-term changes in the environment and fisheries have occurred; for example, a larger proportion of harvestable biomass in the North Sea now occurs as demersal fish instead of pelagics rather than the reverse which was the case between the two world wars. In the North-West Atlantic, there have been several phases where herring and mackerel changed dominance in the pelagic system and similar events have occurred off Peru, Namibia, California and Mauritania over the last decade. As we discuss later, it is not at first sight obvious what is the cause of these types of reverses: overfishing or environment but this simply illustrates the need for the monitoring of such fisheries as total systems.

The time scale between these major kinds of transitions in fisheries systems is, however, usually rather longer than the period in office for most fisheries managers and, unlike the hunter-gatherer tribes of the Neolithic, very few modern fisheries managers reserve comfortable seats in their councils for wise octogenarian fishermen who can remind them of what happened 20-30 years ago when the fishery passed through its last period of transition. When considering the need for this sort of long-range forecasting, it may be useful to briefly list some of the kinds of perturbations that might have a significant impact. Firstly, there are those "intermittent" catastrophies such as tornadoes, floods, tsunamis, stock market crashes and the effect of high and fluctuating interest rates on vessel and plant loans, which are largely impossible to predict with any accuracy but which catastrophic type of phenomena are regularly taken into account in other areas of marine activity such as in the design of seawalls, flood gates, etc. Probably largely for lack of adequate time series, this type of preparation for catastrophe has not been given a great deal of attention in fisheries planning to date. There is growing evidence that some fisheries may respond to a second and more regular type of modulation of the environment which controls the long-term productivity of the system. Various periodicities have been mentioned (see e.g. Gilliland, 1982), some of which may occur more than once within the likely career duration of long-lived fishery administrators; for example, 11 and 22-year regularities (sunspot cycles), 18-year periods (long-term tidal cycle), and 12.8-year periods (oscillations in the diameter of the solar disc) are mentioned as components in, for example, long-term fluctuations in the mean temperature of the northern hemisphere. They presumably must also play a part in marine systems, although here because of the generally short-term preoccupations of most oceanographers, our longer-term series are mostly from fisheries landing data and not from the actual hydrographic factors that drive them.

Periodic factors of the above kind may have a relatively slight direct effect on fish production, operating via changes in annual recruitment level. However, under conditions of positive feedback between the resource (the prey) and the fleet (the predator), they could be one of the factors responsible for the timing of the peaks and troughs in the cycle of landings. While mentioning this possibility, it must be freely admitted that it has rarely been possible to separate unambiguously the effect of long-term environmental changes from those generally more easily measured perturbations due to feedback between the resource and the fleet or fisheries system, and this problem area is currently at the forefront of many fisheries investigations now underway (see e.g. Tanaka, 1980).

EACH FISHERY CYCLE BEGINS WITH A NEW OPPORTUNITY

As in other areas of human activity, new methodologies (or old methodologies applied in new locations) can each create an opportunity; whether this consists of exploiting a new resource, a new method of harvesting or processing or a new market. The successful entry of a few enterprising individuals into a new field often leads to substantial and rapid participation by others; the rate of entry of newcomers only dropping off as the rate of return from the fishery is seen by outsiders to have fallen below the acceptable level warranting investment - this in itself may occur some years

after conditions are already too uncertain for new capital investment by informed investors. These earlier investors, however, may themselves have been able to discount earlier capital investment and be riding on the profits from earlier, higher abundance years or be in a better strategic position to obtain subsidies, since the failure of their enterprises will lead to unemployment in the fisheries sector which is often viewed unfavourably by governments. All these factors, together with the fact that investment decisions by independent-minded fishermen are independent and are influenced by evidence of past success (large cars, large mortgages, etc.!), provide reasons why the beginning of an uncontrolled fisheries cycle will generate excessive effort in the first few years of a fishery which will not easily be dissipated later on until fleet attrition occurs.

Whatever the criterion for sustainable yield (and the effort giving MSY is now known to be excessive), some examples (Table 1) show that from the onset of industrial fishing to (e.g.) MSY conditions is a relatively short interval, given modern technologies (see Table 3). Clearly, the speed of mobilization of modern investment is such that the management authority has little time for action if it intends to place the fishery under management. It is even reasonable to propose that it is the rate of investment in this early phase that is the key to whether the fishery is manageable in a positive as opposed to a repressive fashion later on in the same cycle.

FISHERIES SYSTEMS HAVE THEIR OWN DYNAMICS AND DO NOT ACT IN ISOLATION

It seems important to emphasize that the fishery, treated as a system, has its own internal dynamics, laws and evolution and is not a closed system since it depends on inputs from the environment and from other sectors of the economy. Some examples of physical inputs are the impacts of environmental fluctuations or interaction of a resource with its own predators, prey or competitors (and their effects on the stability or persistence of the resource). At the other end of the scale the fishery obviously depends on prevailing socio-economic conditions, levels of alternative employment, etc. to determine the availability of fishermen, appropriate fishing methods, level of investment potential and actual markets. A manager of such a system is obviously constrained by four main types of factors:

1) The availability of information on what changes in the resources and markets are occurring or are likely to occur in the near future.

2) The existence of policies and guidelines that tell him what is the appropriate objective for the fishery.

3) The accuracy of his conclusions and decisions as to what needs to be done to achieve these objectives.

4) The extent to which the general inertia, governmental priorities and availability of societal mechanisms allow him to achieve these objectives.

Treating these points in sequence reveals the following considerations, which we recommend for attention by the Consultation:

Point 1 :
Rarely do we have adequate information on the resource that gives us an unambiguous answer to the question of what the resource will do over the next few years. We may with time and analysis be able to make some predictions, but must be prepared for the consequences of poor choices. As far as markets are concerned, we may be in a rather better position, but here again recent world events have proved difficult to forecast and the same considerations must largely apply, as far as exports and demands are concerned, as for most other food commodities.

Point 2 :
Often national fisheries policies are implicit (not stated) or confusing and contradictory, leaving the manager to make most of the decisions. Political influences may also change or impose a shorter-term scale than is needed for proper fisheries management.

Point 3 :
The models available to fisheries managers to date have been very simplistic and include as inputs only a proportion of the available data which could be used for arriving at a proper decision. If, for example, fishing effort accounts for 50 percent of all physical impacts on the catch rate or on the total landings, decisions based on this variable alone will inevitably have a high degree of uncertainty as to the probable physical yield, without even considering socio-economic factors.

Point 4 :
Following on from the above, we note that fisheries are often a small sector of the national economy or cultural milieu, and hence decisions cannot be taken in isolation from extrinsic considerations operating in other sectors of the economy.

Taking Points 1 to 4 in concert, one is forced at first glance to conclude that the manager is in a nearly impossible position. In reality, things are not quite so bad as this, since some very loose guidelines are implied in the literature on various aspects of fisheries management and there is now available a body of experience in world fisheries that grows yearly. This experience seems to suggest the following things:

1) Attempts to tune a system for attainment of maximum output (MSY) will lead to oscillation, unpredictability and, because of the inertia of the socio-economic system, eventually to crashes (whether reversible or not). A lower level of expected output is safer and more predictable.

2) The response time of the system to changes will not be less than the time scale of the main components of the system. Some of these critical time scales are:

   a) The average generation time of the species harvested in the system.

   b) The average life span of boats, plant and duration of participation of active fishermen in the fishery (itself a function of their degree of mobility).

   c) The period of oscillation of key environmental variables and, much less predictable, the average interval between cataclysmic events (e.g. hurricanes, wars, economic crashes, etc.) which might have an impact on the system. In the case of more regular periodic fluctuation in the production system, although these effects may be slight, it may be possible that the production system will fall into phase with these. Similarly, the production and harvesting sub-systems may be expected to fall into phase with the various economic cycles that have been postulated. In both cases, feedback in the fisheries system could accentuate these periodicities, due to the built-in feedback loops and lags in the fishery.

3) The instability of a fishery and the tendency to oscillation will be increased by a significant time lag between detection of a problem and the onset of the appropriate management response.

4) Attempts to attain new objectives too rapidly in the management process will result in system oscillation. Although arguments have been advanced that pulse fishing will harvest a greater proportion of a given cohort, as we will see later, this is a tenable approach only where production is very irregular. The fallacy of this argument is that most of our models, biological as well as economic, are based on the idea that equilibrium conditions and hence recruitment are maintained constant during the process. It must be clear to everyone that the rapid attainment of MSY conditions from zero or low effort levels will not be conducive to attainment of any equilibrium until at least the longest expected generation time of any component in the system, whether fish, boats, plants or men, has been exceeded.

One consequence of 4) is the so-called "ratchet" principle, whereby an isolated fishery may increase its effort rapidly but, because of the long generation time of the harvesting units, the fleet size will not decrease rapidly due to few alternative resources to harvest. It is perhaps worth noting here that, in the past EEZ era, for most national industrial fisheries except those within very large fishing zones, the number of alternatives for such specialized industrial fleets are very limited.

The fundamental rule suggests itself, namely that a manager should attempt where possible to dictate the direction of change but try and assure that this occurs slowly, steadily and smoothly over a significant period of years, with continual reflection and comparison of the results of management by "feed back" with earlier years. In a scientifically managed and basically stable fishery, we may even suggest an alternative "experimental" management regime, in which any increase in effort should be separated by at least a generation time for the species forming the resource, in order that its impact is fully appreciated before proceeding further. One may even speculate (Figure 4) that, by changing the 'direction' of the teeth of the ratchet, intrinsically produced oscillations may be damped out; in other words, effort should be increased slowly, leaving time for appropriate feedback but, if sudden changes must occur, these should be abrupt drops in effort in response to signals of stock depletion. Despite some of the obvious practical difficulties of this approach, it at least deserves some attention as a possible overall strategy.

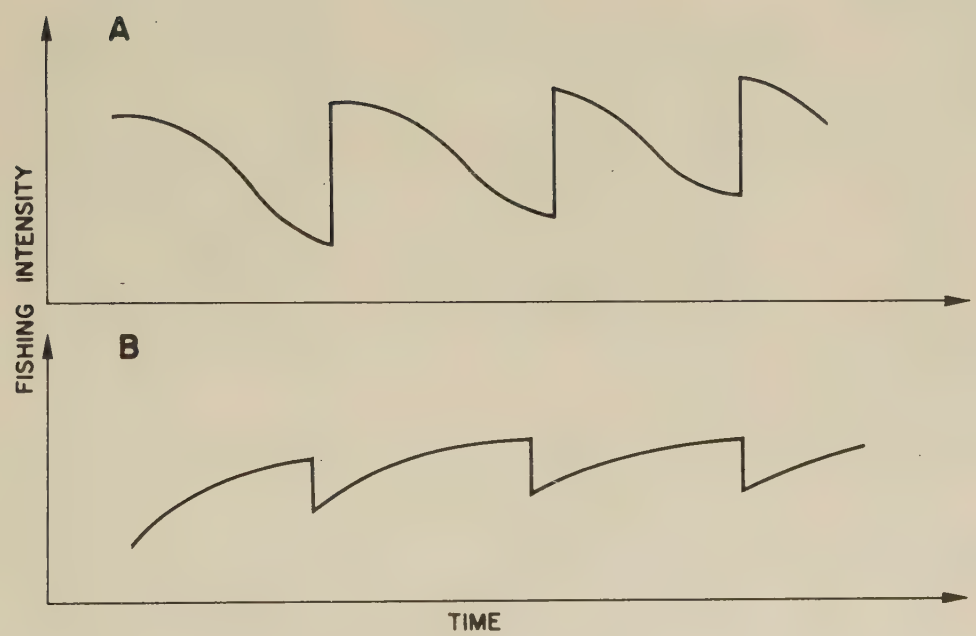


Figure 4 Desirable (A) and undesirable (B) patterns of application of fishing effort

CLASSIFICATION OF SPECIES AND ENVIRONMENTS

Any kind of over-generalization will inevitably prove incorrect in a system as complex and multifactorial as most fisheries systems are and, in order to make any progress, it will be necessary to adopt some method of classification, however preliminary. One of the currently most popular of these, originating from terrestrial ecology, is the so-called r-K scale of specialization (MacArthur, 1967), which has been adopted with some partial success and qualification in marine ecology also (Table 3). This approach notes that the evolutionary strategies of species tend to lie somewhere along a gradient between two extreme types of adaptation. The first denotes short life spans and high rates of reproduction and growth for species with small, generalized body form, that are well adapted to periodic 'blooms' or recolonization of unstable environments. For such species, e.g. sand eels, squid and trigger fish, populations may expand rapidly in response to a combination of favourable environment and low abundance of K-adapted species (e.g. caused by heavy fishing) and die away equally rapidly in response to unfavourable environments. The K-adapted species, by contrast, are generally long-lived and slow growing, with relatively stable populations showing well-developed adaptation to individual survival. A comparison of some of the supposed characteristics of the r-K extremes are shown in Table 3.

Table 3 Some of the characteristics of r- and K-selected species

Characteristics	r-selected	K-selected
Climate	Usually variable and/or unpredictable	Fairly constant and/or predictable (or species shows migratory behaviour)
Risk of natural death	Often high or catastrophic, largely independent of population size	More scheduled death rate, dependent on population size
Population size	Variable in time, non-equilibrium conditions prevail; occupies ecological vacuums but rarely reaches carrying capacity of vironenment; recolonizes each year	Fairly constant in time, at or near carrying capacity of environment; no recolonization necessary of saturated communities
Competition between species and within species	Generally lax	Usually keen
Length of life	Short (usually less than one year)	Longer (usually more than one year)
Natural selection in favour of:	1) Rapid development	1) Slow development
	2) High rate of population increase	2) Low rate of population increase
	3) High rate of egg production	3) Low rate of egg production
	4) Small body size	4) Large body size
	5) Single reproduction	5) Multiple reproduction
	6) Less emphasis on behavioural and morphological characteristics to increase individual survival	6) Well-developed feature giving good individual survival, e.g. territorial behaviour, spines, special dentition and special feeding habits
All above lead to:	Productivity	Efficiency

Judged from this perspective, r-selected species would seem less manageable than K-selected ones. This conclusion must be regarded with caution, however, because such a simple two-way classification does not take into account the main categories of environment seen in marine systems (see e.g. Shepherd et al, 1982). In particular, it seems quite possible for a short-lived r-selected species to achieve and maintain dominance in a stable environment if the population of K-scheduled competition species is kept low by fishing. An example of how this may occur is shown for squid populations in Figure 3.

With this in mind, a rather better classification into three main categories of species has been proposed by Kawasaki (1980) that leans heavily on Japanese experience in N.W. Pacific Ocean fisheries (Table 4).

Table 4 Correlates of three selected types of life history in the marine teleosts (after Kawasaki, 1980)

	Type I		Type II
	Sub-Type A	Sub-Type B	
Environment	Irregular variation ← Variable and unpredictable →	Long period variation	Stable and predictable
Recruitment	Irregular variation ← Variable →	Long period variation	Stable
Resources put into:	Reproduction only ← Reproduction →	Reproduction & maintenance	Growth and maintenance
Lifespan T	Short	Long	Long
Growth: Gr. rate KT	Moderate	High	Low
Max. size L	Small	Moderate	Large
Reproduction: Age at first maturity, m_x	Very low ← Low →	Quite low	High
Fecundity	Low	Moderate	High
Intrinsic rate of population increase	Very high ← High →	High	Low
Early survival	Variable		Stable
Trophic level	Low		High
Typical species	saury, sandeel	sardines, herrings	cods, flatfishes
Appropriate management measures	Catch forecasting and monitoring + pulse fishing	Recruit forecasting & yield/recruit assessment & MSY fishing?	Equilibrium yield assessment, steady state ($F_{0.1}$) fishing

Here two main and two subsidiary classifications of species are proposed: Type II being similar to the K-selected category above, except that number of eggs produced per spawning is high and includes, as examples, cods and flatfish (e.g. Type 4). Being generally high in the food chain, these species may be considered manageable by conventional yield models, with equilibrium concepts being relatively applicable.

Type I is divided by Kawasaki (1980) into:

Type IA - small short-lived species with low individual fecundity but very early maturity, early spawning and hence high rates of population increase. These species (e.g. saury, squid and sand eel) tend to inhabit irregular variable environments and show high population variations, making them essentially very similar to the r-classification earlier (except for low fecundity), and may be considered non-equilibrium stocks where pulse fishing may be the only way of harvesting the stock without excessive wastage due to natural deaths. Here the manager is faced with the conflicting considerations of deciding between a high enough effort level that reduces wastage and a high possibility of the need for alternative fleet deployment to other resources if population crashes occur, as they inevitably will at some point with this type of stock (e.g. Figure 5). The possibility of joint ventures or licensing of foreign effort seem alternatives for disposing of temporary surpluses.

Type IB - Here we have stocks adapted to areas with long-period fluctuations or cycles in suitability of the environment within the cycles. This group is somewhat intermediate between the other two in that life span is long enough, but age at maturity is generally early, with multiple spawnings and moderate fecundity to allow a rather high build-up of population biomass over the medium-term (5-10 years?) period of favourable conditions and with sufficiently long life span for some individuals to survive to the next favourable period (e.g. sardines, herring).

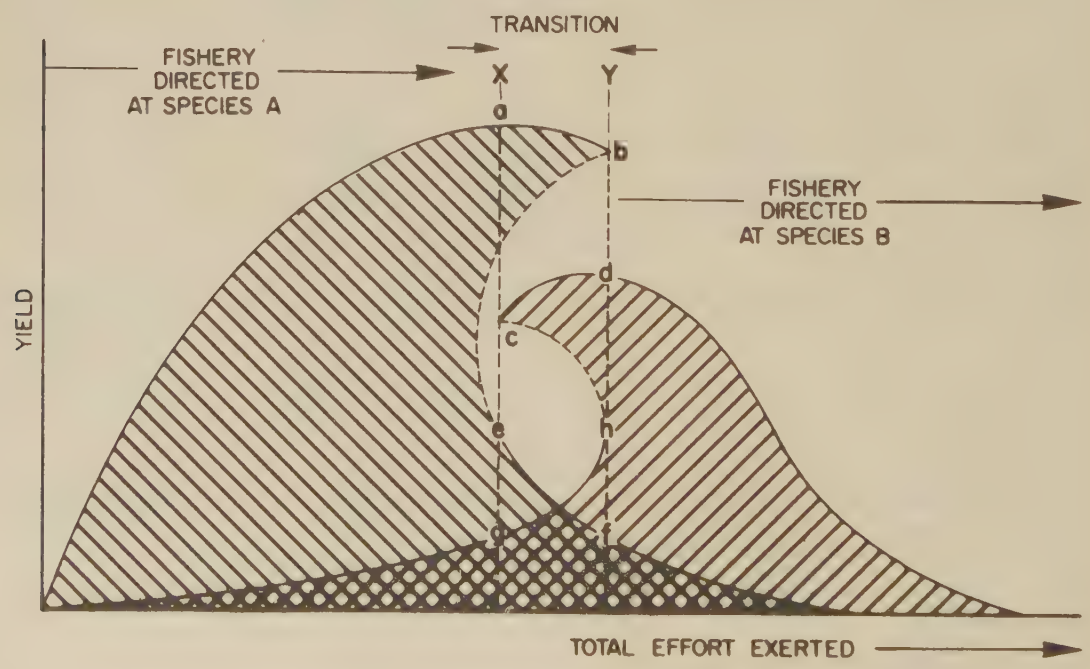


Figure 5a One way of visualising a transition from a fishery directed at a species A with by-catch of species B to one on B with by-catch of A. It is supposed that in the period of transition, yield of A lies somewhere between "metastable" conditions shown by segments a-g and e-f, and similarly for B between g-h and c-d. No equilibrium conditions occur in this area and the transition is likely to occur over a short period of time. Such transitions can be described as "catastrophies".

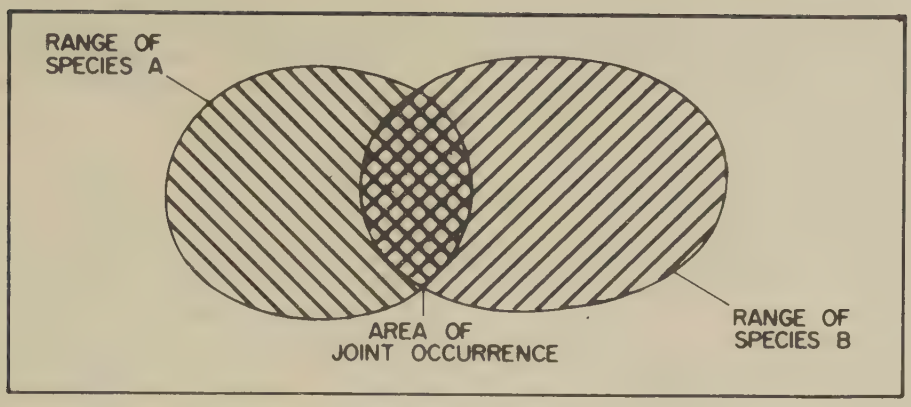


Figure 5b Another way of visualising how the above transition can occur in spatial terms. Fishing is initially over the "range" of A with by-catch of B in the area of overlap, but following decline of population A the fleet moves to the right hand oval (species B "range") with by-catch of A. (N.B. "Range" here could mean geographical extent, but may more realistically be considered the seasonally adjusted fraction of the stock available by fishing including depth, availability, etc., i.e. a move from A to B could either imply a change in availability or a new method of harvesting.)

From a management point of view, this group of species is perhaps the only one where a period of rapid increase in effort is appropriate but even here the build-up of a specialized fleet much in excess of what the long-term average population can support will result in serious over-capitalization between peaks. Here the appropriate strategy is probably the temporary licensing of extrinsic units during periods of high production or spreading the production from good year classes over several years.

THE EVIDENCE FROM LONG-TERM LANDING TRENDS

Although the preceeding classification scheme has much to recommend it, we may ask whether it is sufficiently generalisable outside the somewhat special conditions that prevail in the North-West Pacific. Specifically, is it possible that the same species classified as Type I (unpredictable) might in fact become Type II in more stable environments? The answer to this seems a qualified yes (the qualification being that species close to the base of the food pyramid, especially if co-existing with a competitor species, may still be liable to large population perturbations). It may be more valid and immediately generalisable and relevant to fisheries management to classify instead the fisheries, thus taking into account not just the species in question but also its environment. Another relevant point is that the degree of stability of a system may be a function of the degree of impact of man on the system. This theme is, of course, one of the major concepts underlying this paper.

Figure 1 of the Appendix shows a broad general classification of fisheries that parallels in some respect that for species by Kasawaki, and has four basic categories with characteristics as follows:

1) Fisheries with relatively constant annual yields that approximate to conditions of "steady state" production
2) Fisheries with regular periodic fluctuations
3) Fisheries with fluctuations of irregular periodicity
4) Environmental (biotic and abiotic) instabilities

Category 1) corresponds roughly to Type II of Kawasaki, categories 2) and 3) are included in his Type IB, while category 4) corresponds to Type IA. The reason for dividing up Type IB is that from a management point of view the implications of regular (predictable) versus irregular fluctuations are quite different. In the first case some forecasting is theoretically possible. In the second, this is relatively infeasible without continuous and costly recruitment monitoring and then only for a year or two in advance. Examples of these four categories are given in Appendix I.

STABILITY AND CATASTROPHIES IN FISHERIES SYSTEMS

The concept of equilibrium yield that underlies most fisheries models implies that if effort is maintained constant, yield from the system will tend towards an equilibrium value for that level of effort and will eventually come to lie on or, in the case of stochastic versions of the model, somewhere close to the line described by the mathematical function used (Figure 1 of Appendix). In the course of fitting these models, it is usual to employ some kind of averaging procedure that corrects for departures from equilibrium conditions, rather than fitting the model to the raw catch and effort data from the fishery. The degree of scatter around the line is still considerable in many cases (e.g. Figure 3A), and it is clear that even if the model provides a reasonable description of "average conditions" over the years for which the data were available to fit the model, it rarely permits a reliable prediction of the yield which may be expected the following year, even if the fishing effort can be forecast.

One other problem that is not always explicitly recognized is that the usefulness of models of this kind tends to decrease as the peak (MSY) conditions are approached, at which point the biomass of the stock is down to around half of its unexploited size. Close to this level of exploitation, production from the system usually becomes more erratic so that the effects of a given level of effort are even less predictable. As we have already seen, if recruitment is poor in 7 years out of 10, a particular preset catch or quota that would have only corresponded to a low level of exploitation during years of high recruitment may now correspond to severe overfishing. The generally poor descriptive powers of most existing fisheries models in the face of high intensity of fishing continues to deteriorate to the right of MSY, such that in many cases stock collapses may occur well before they are predicted by equilibrium models.

One way of describing what happens beyond the MSY level, even if only qualitatively, is by means of so-called 'catastrophe theory' (e.g. Ekeland, 1977). This in its simplest terms says that a catastrophe (or very rapid discontinuous change in a system) can occur where two very different situations are equally feasible from the point of view of the energetics of a system. This may be illustrated by Figure 5 (the "clashing tsunamis" model) which shows a fishery directed to a species A (e.g. a sardine resource) with a small by-catch of a second species B taken incidentally in the fishery (e.g. anchovies). Perhaps species B occurs only in part of the range of species A (as in Figure 5B) or is only taken with low efficiency by the gear designed to catch species A. In any case, by the time fishing effort has reached level X, the catch rate of species A will have dropped or become more erratic, even though the total yield of A is kept high by intense fishing. Somewhere between fishing effort levels X and Y there is a serious sustained drop in the yield of species A from line a-b to line e-f and, soon after, an increase in the landings of species B from line g-h to c-d, because the fleet has now overcome problems in harvesting this new resource or has moved into the main area of availability of the resource (Figure 5B) and is now fishing for this species and taking species A as a by-catch.

This very hypothetical illustration is intended to provide one way of visualizing how abrupt transitions in resources may occur. Although abrupt transitions may occur naturally due to environmental changes for certain categories of species, there are grounds for believing that heavy fishing pressure and its abrupt application may accelerate the process even in otherwise manageable systems.

OSCILLATIONS IN FISHERIES SYSTEMS

Classifying phenomena along a scale from manageable to unmanageable, we may consider that systems showing oscillations fit somewhere between steady state behaviour and population crashes. Regular periodic fluctuations are common in fisheries statistics and it would be worthwhile looking briefly at some of the possible underlying mechanisms.

Since we are dealing in fisheries with potentially oscillating systems and how to control them, it is worth briefly considering a fundamental concept from the field of cybernetics, the idea of feedback. Freely modifying the definition in Webster's Dictionary, for our purposes we have positive feedback defined as the use of information on the output from a system to increase the amplitude of an oscillation, and of course vice versa for negative feedback.

Looking at the simplest and most widely quoted predator-prey model, that due to Lotka and Volterra (Figure 6), we see that changes in population size of a single predator and its single prey are a function of rate of change of the population size of each other, such that predator and prey populations both oscillate out of phase (Figure 6); predator populations growing rapidly to a peak immediately following years of abundant prey and, in consequence, cropping down the prey population to a low level. At this point, starvation sets in with increased death rate or reduced birth rate of predators and this in turn leads to an explosion in the predator population, and so on indefinitely. Although it is possible to define an "equilibrium" point (AB, in Figure 6 A_1), this is not necessarily ever attained but perhaps corresponds to the average predator and prey population respectively, around which the true values move in an elliptical fashion in what can be referred to as a limit cycle (Figure 6 A_1). Such systems are well known in terrestrial biology, e.g. the lynx-snow shoe rabbit oscillations that showed up in the long-term records of the North American fur-trading companies (Moran, 1953). They are rather less well documented in marine biology, for reasons not only of short time series but perhaps because food webs in the marine systems have many linkages, so that a single prey and its obligate predator is not an especially common phenomenon. Marine predators can often transfer between a preferred prey and one or more alternates if the first is depleted, a situation which is also ideally achieved in multipurpose fisheries such as some artisanal ones. The other real problem in documenting such predator-prey linkages is that, for industrial fisheries, the impact of the fishery on the prey outweighs that of the natural predator(s) in question and in fact a fishery aimed at a single species soon takes over the role of principal predator and overshadows other multispecies relationships that are operating in the system. This can lead to the types of oscillation in predator and prey abundances described earlier, with the fleet taking over the role of principal predator.

One of the main roles of fisheries management may then be to control the effort input in such a way that oscillations in both populations and supply and demand are reduced. Figure 7 illustrates in hypothetical form the possible impacts of the intensity of perturbation (environment or fishing intensity) on the yield from a given steadily oscillating resource.

The conclusion we have already reached is that oscillation in fisheries production can be due to both extrinsic (e.g. environmental) factors as well as the impact of the fishery itself. Most fisheries models tend to consider that fishing effort (being the only variable that is theoretically controllable in most cases), outweighs the environmental effects which can just be considered as "noise" in the system. If this "noise" is very substantial, however, we will need to consider its impact more carefully in deciding whether it is even practical to attempt management on the basis of effort control alone, especially since the data sources available usually are inaccurate enough to contribute considerably to the error or variance term in the "signal" or data received by the manager. A later section discusses this question. For the moment, we note that models of fisheries yield have a large random component and this is one of the reasons why medium-term predictive models (as opposed to short-term forecasts and long-term or "equilibrium" predictions) are so rare in fisheries science and management.

Equilibrium models are useful in providing some guidelines as to the possible impact of a given level of harvesting, should all other conditions remain constant. It is a mistake, however, to assume that the system itself is an equilibrium one or tends to equilibrium. This can be illustrated simply by the fact that although equilibrium models suggest the long-term average yield that will result from a given level of effort, they do not in themselves allow you to predict or explain why fishing effort changes in the often rather repetitive fashion it does.

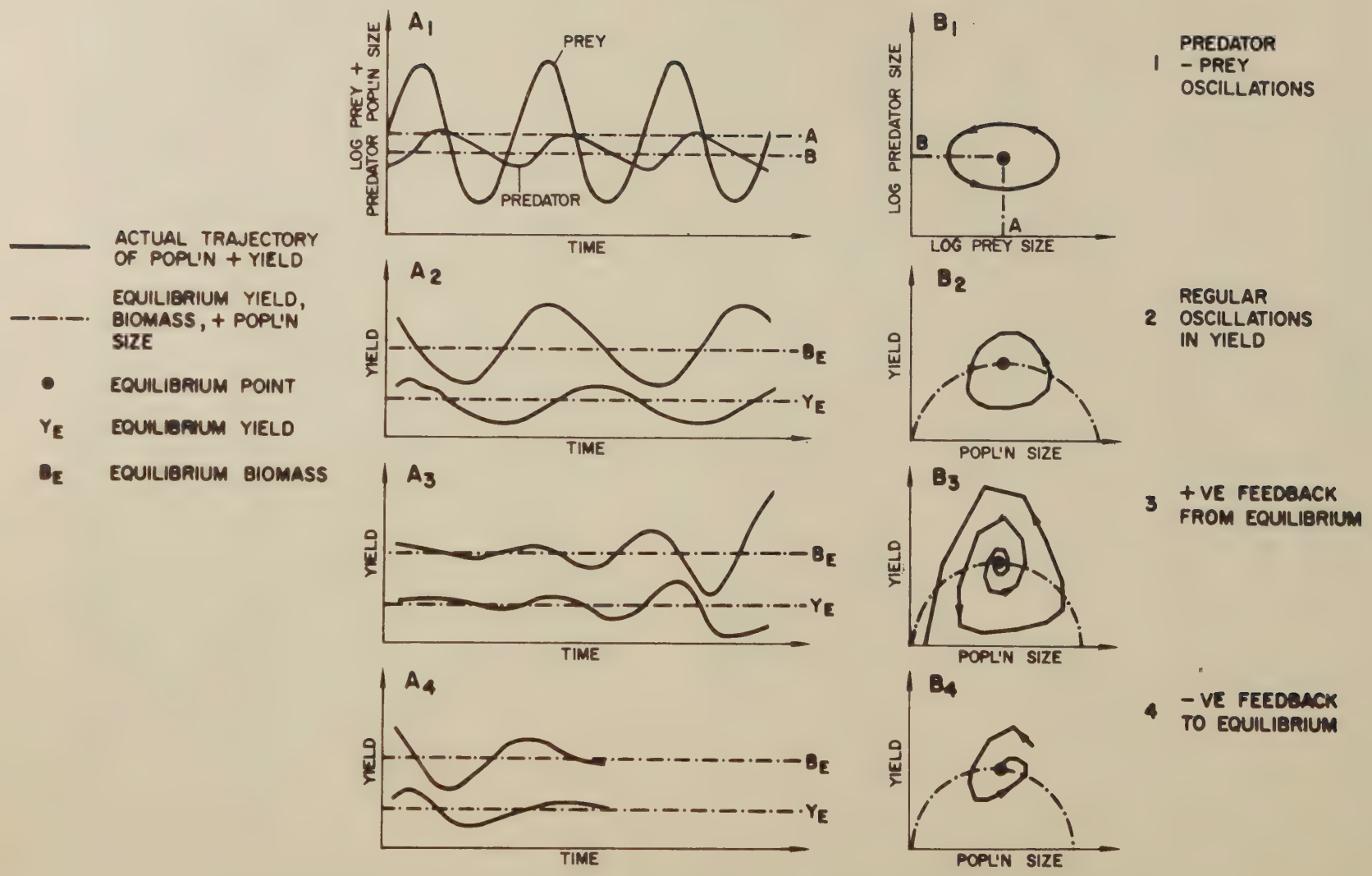

ACTUAL TRAJECTORY OF POPL'N + YIELD
EQUILIBRIUM YIELD, BIOMASS, + POPL'N SIZE
EQUILIBRIUM POINT
Y_E EQUILIBRIUM YIELD
B_E EQUILIBRIUM BIOMASS
A_1
LOG PREY + PREDATOR POPL'N SIZE
PREY
PREDATOR
A
B
TIME
B_1
LOG PREDATOR SIZE
B
A
LOG PREY SIZE
1 PREDATOR - PREY OSCILLATIONS
A_2
YIELD
B_E
Y_E
TIME
B_2
YIELD
POPL'N SIZE
2 REGULAR OSCILLATIONS IN YIELD
A_3
YIELD
B_E
Y_E
TIME
B_3
YIELD
POPL'N SIZE
3 +VE FEEDBACK FROM EQUILIBRIUM
A_4
YIELD
B_E
Y_E
TIME
B_4
YIELD
POPL'N SIZE
4 -VE FEEDBACK TO EQUILIBRIUM

Figure 6

A_1 Oscillations in linked populations of prey and predator populations with time.

B_1 Illustrating the difference between an "equilibrium" position * and the dynamic relationship between predator and prey populations.

A_2-A_4 Oscillations in biomass and equilibrium yield with time where man is the principal predator.

B_2-B_4 Trajectory of biomass-yield relationships super-imposed on equilibrium yield curves for the population, and showing the equilibrium point as a dot.

A_2/B_2 Regular oscillations.

A_3/B_3 Amplification of the oscillations (positive feed-back) and progressive divergence from equilibrium.

A_4/B_4 Damping down of the oscillations (negative feed-back) and convergence on equilibrium.

(Redrawn from Tanaka, 1980)

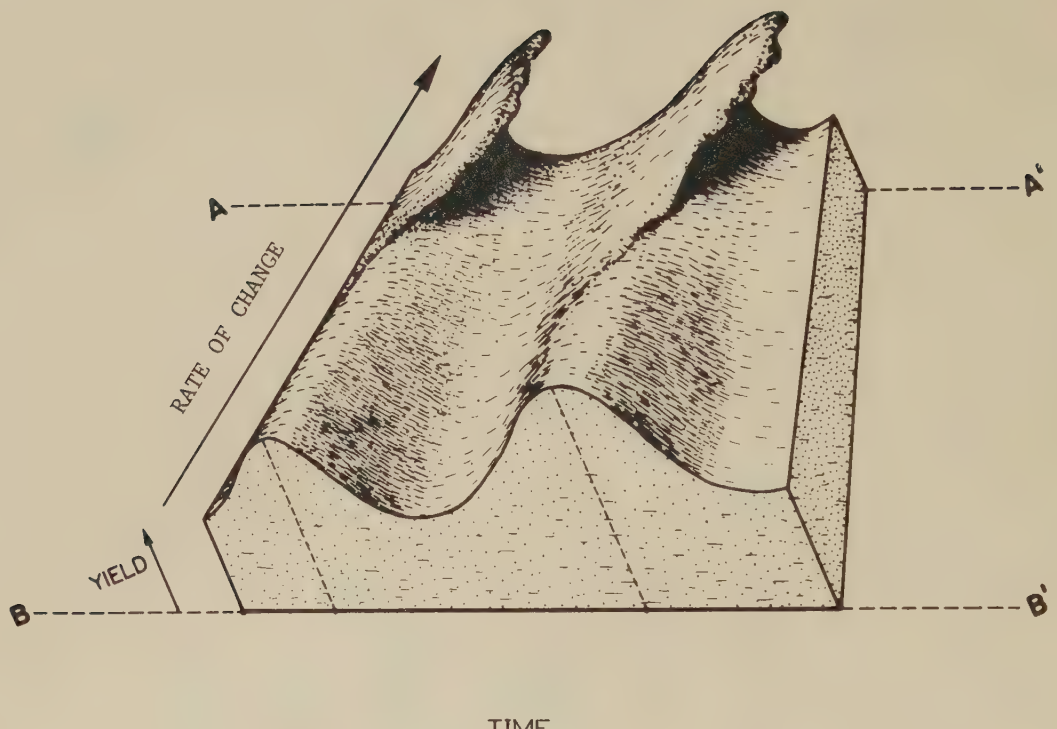


Figure 7 The theory of Catastrophes of Rene Thom freely interpreted to show how progressively more rapid application of effort, especially in the expansion phase, may lead to a transition from 'near equilibrium' conditions to successive population crashes.

(Similar crashes can be caused by environmental modulations which can result in a larger population existing at any one time than the environment can now support.)

THE CONCEPT OF A "FISHERIES CYCLE"

One of the usual truisms offered as a description of the "wild" fisheries is that, however technologically sophisticated, they are the modern equivalent of the neolithic hunter-gatherer mode of life that preceded territorial agriculture. This appears somewhat of an optimistic statement, in that the "primitive" societies in question had well developed strategies of seasonal harvesting of resources, area closures mediated by migrations to allow stocks to recover, a generally circumscribed number of harvesting strategies with very finite efficiences, and a form of population control that ensured that the predator population (themselves!) did not exceed in size the ability of the prey population both to sustain harvesting and to allow it to compete with other perhaps non-harvestable members of the ecosystem. None of these features are conspicuously common characteristics of most modern fisheries systems.

Artisanal fisheries have been put forward as examples of systems where the harvesters and prey are in some kind of loose symbiosis with each other. Evidently this was true for many coastal communities that depended very largely on the sea for their food, prior to the recent rapid advent of technological changes. Early methods of harvesting were either inefficient or only exploited a small (inshore) fraction of the stock. It is certainly less true with the advent of new technologies (e.g. outboard motor, monofilament gear, etc.). We may even have some serious doubts that the above concept of equilibrium (viewed as stasis or roughly constant population sizes of predator and prey) was particularly common even for aboriginal artisanal fisheries - particularly if dependence on a very few prey items increased the possibility of oscillations in population size of predator. (Oscillations of this kind would be less likely or drastic in their effects if a variety of prey types could be harvested which, of course, is usually the case with artisanal fishermen.)

Given the considerations described so far, it may help the deliberations of the consultation, on the question of regulation of fishing effort and mortality, to be presented an alternative working hypothesis to the equilibrium model of fisheries. As such, the following provides a very generalized description of what is often loosely referred to as the "fisheries cycle". (Similar classifications have been prepared earlier by other workers: e.g. Kesteven, 1973).

The idea that there may be stages of growth and decay in fisheries systems has often been left unstated, perhaps largely because it seems too obvious to formalize as a hypothesis but perhaps also because of wide individual variations that make identifying the stages and duration of such a cycle difficult and variable, both in different fisheries and in the historical succession of events in the same fishery.

The concept of a cycle which does not have a fixed periodicity is in fact somewhat of a misnomer mathematically, but the term is retained because it corresponds best to popular usage of the word "cycle". Such a conceptual model may prove a useful descriptor of the system even if, like other similar mental constructs used elsewhere (e.g. the Wall Street 'cycle'), it can lead to problems if followed without a certain degree of healthy scepticism. The period of the cycle will be related in this case, of course, to the active life span of the oldest component in the system - that is the fleet and the fishermen.

The proposition put forward here is that the fisheries cycle is a sequence of events that probably occurs in a more or less extreme form in any (particularly single species) fishery in the absence of effective management. Each new 'cycle' is initiated by a new wave of over-investment in the fishery (Figure 8).

The sequence of initial over-investment, rapid growth of mortality levels to those in excess of most conventional optima, subsequent departure or loss of fishing units without replacement, final decline in effort and subsequent recovery of catch rates and stock size to a level where a new cycle is initiated, is suggested as the null hypothesis against which fisheries managers may measure their performance.

In this sense, the objective of effective management is presumably to attempt to "freeze" effort and mortality levels in some favourable transitional state as long as possible and to minimize the duration or destructive impact of less favourable stages in the cycle.

Basic to the above statement is the proposition that it is unwise to assume that favourable fishing conditions are necessarily stable. Also implied here is the prediction that particular types of interventions or management measures will not be equally effective at all stages in the evolution of a fishery. This question seems to merit some discussion by the Consultation since it has implications for both fisheries management and development.

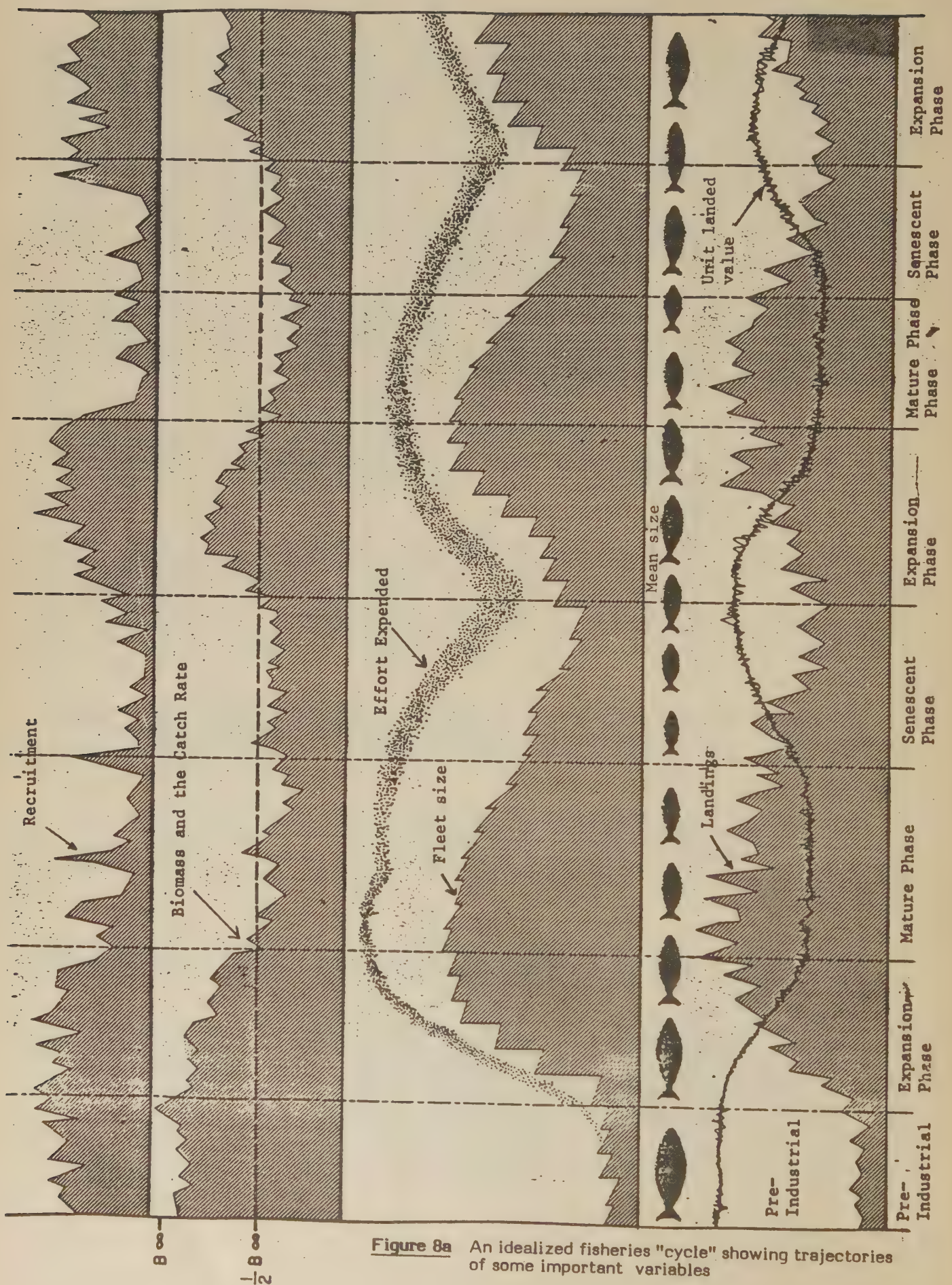


Figure 8a An idealized fisheries "cycle" showing trajectories of some important variables

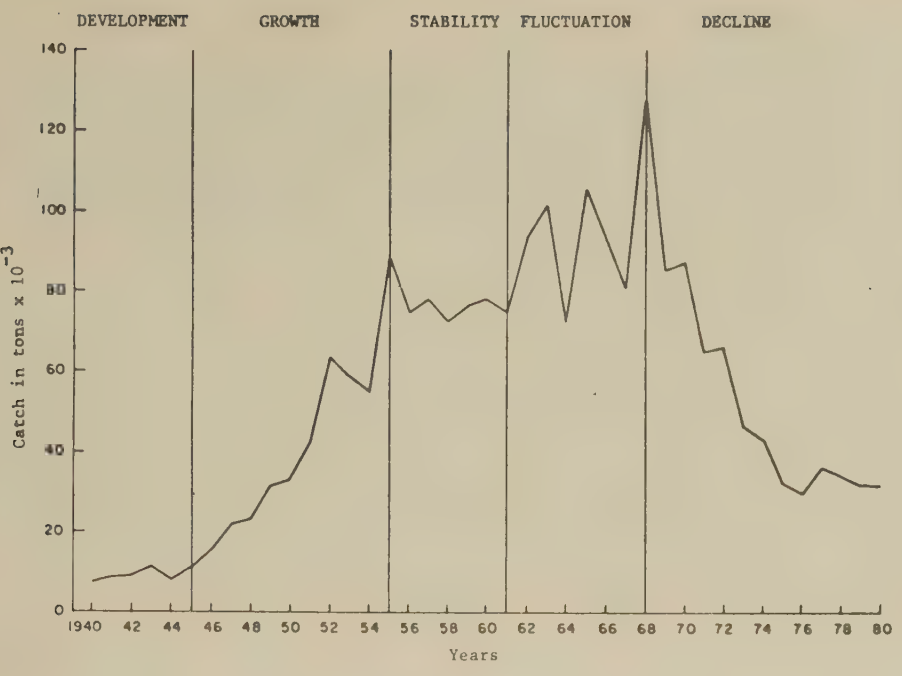


Figure 8b

Historical landing trends for the Chilean hake (Merluccius gayi gayi) (from Aguayo and Young, 1982) showing application of a similar classification of the fishery into stages, using the scheme proposed by Kesteven (1973).

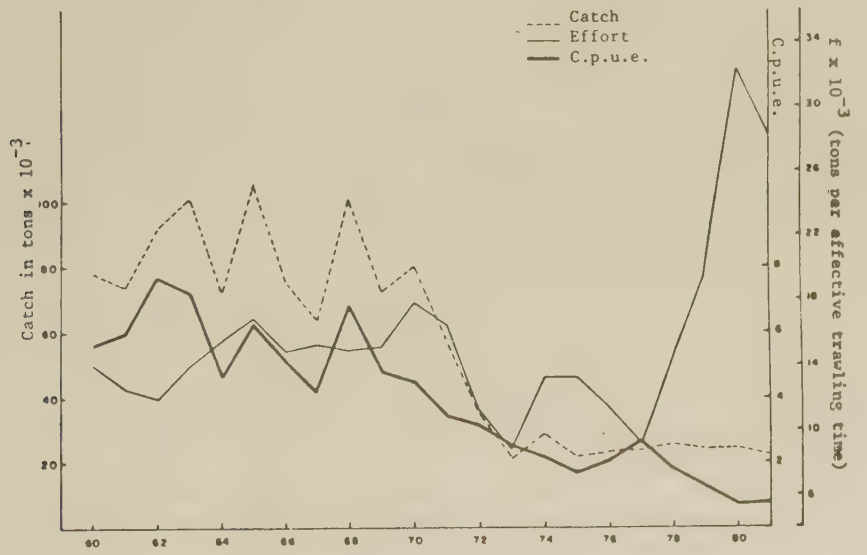


Figure 8c

Historical data series of catch, effort and catch rate for the same stock, from Aguayo and Young (1982). It seems that following the first cycle that ended with declining yield, effort and initially catch rate in the early 1970s, a new cycle of rapidly growing effort, well in excess of potential yield increases, began at the end of this decade. Judging from this figure, slightly increasing catch rates in the mid-70s may have played some part in triggering this excessive response, but interactions with counts in other Chilean fisheries in the 1970s were also important.

THE PRE-INDUSTRIAL PHASE

Many new industrial fisheries arise because some artisanal or sport fishery, or the by-catch from a fishery directed at some other resource, indicated the existence of a larger resource which these fisheries were unable to exploit fully. As noted earlier, the start of industrial-scale harvesting usually follows recognition of an economic opportunity by a few individuals prepared to risk capital in the new venture. Their success over the last few years of this stage presumably then attracts larger funding, either governmental, private or international, leading directly into an expansion phase.

THE EXPANSION PHASE

Perhaps because either decisions in the expansion phase of investment in fisheries development are taken independently but during the same short interval by a number of individual investors or fishermen and/or because the time lag between the investment decision and new boats or plant coming "on-stream" is fairly prolonged, there is in consequence a tendency for over-capitalization to occur in the expansion phase. As a result, there is an effort overshoot relative to that level of capital expended and effort exerted which would achieve the best overall level of benefits for the industry as a whole. Although the precise event which turns off the flow of investment in the later years of the expansion phase may not be a simple one, feedback of information on performance of the fishery is often masked by random fluctuations and, as illustrated earlier, takes time to be accepted and acted upon. One way of defining the end of this phase is when the originally high average catch rate and benefits per unit effort for the fleet fall below some preset figure. The Consultation is invited to consider what events in fact lead to the switching off of effort in fisheries they are familiar with. In the example given, this is shown as corresponding to half the original unexploited biomass of the stock but this may be far from generally the case.

Two typical types of situations may be seen in the early development of a fishery:

1) If a more ordered "autochthonous" development of an industrial fishery has been followed (i.e. as an outgrowth from an existing small-scale industry), a cross-section of the industry at this time will reveal a bimodality in the harvesting sector and possibly also in the processing and marketing sectors. There will be on the one hand a fleet of small vessels, crewed by inhabitants of coastal communities with both boats and crew showing a broad cross section of age groups, possibly dominated by older fishermen and fishing with traditional gear including handlines, various types of seine and fixed gears, each of which has its own selectivity for species and size, and where a pronounced territoriality in areas fished is evident. Marketing is likely to be of fresh fish and preserving the catch restricted to traditional methods, including drying, salting, etc. On the other hand the industrial fishery, made up of new vessels, will make up a prominent and separate section of the fishery. The crews of the industrial vessels may in part come from the same coastal communities but are likely to be younger and may include a proportion of non-locals with particular skills not readily occurring in the traditional coastal community.

2) It is frequently the case that the industrial sector has been grafted onto a societal and economic background where the resource in question was relatively unknown previously. Examples are provided by joint ventures with foreign companies for deep-sea resources, where local participation is still minimal and where the distant-water company still has a monopoly of economic resources, equipment and skills.

Early in this expansion phase, particularly in case 1) above, it is likely that gear and other conflicts between artisanal and industrial fleet components will remain minimal. With respect to markets, since fish may still be in relatively short supply and high priced (especially for the export market in communities distant from the coast and not formerly served by the marine artisanal fishery), the degree of conflict between markets for these two sectors of the fleet initially should not be extreme.

THE MATURE PHASE

Stock abundance will soon begin to decline in the main fishing areas but to some extent these declines are likely to be compensated for by the location of pockets of high abundance, a better understanding of seasonal fluctuations in availability patterns, increased effort per unit vessel and improved fishing skills of participants in the fishery. Learning factors will come to play a major part in maintaining catch rates at high levels, despite generally lower abundance levels.

Nonetheless, a decline in retail prices towards the end of this phase may result partly from greater supply and partly because of competition within the industrial section or because of economics of scale (in processing and distribution). This may have an adverse impact on the artisanal fishery if the latter shares the same resource and market sectors. We may note that this adverse impact and the poor resource condition that underlies it will tend to persist if subsidies are used as a means of maintaining surplus effort in the fishery in this phase and in the next.

Towards the end of this phase, catch rates for the industrial sector will have dropped significantly (perhaps to less than half of the initial catch rate) and the average size of fish caught will have declined. More irregularities in abundance of the smaller sizes (recruits) may be evident now, since not only is stock replenishment likely to be more irregular but, because new recruits now play a larger role in the catch, dependence on the incoming year-class strength is more evident.

THE SENESCENT PHASE

Catch per hour fished will now be generally lower than formerly and greater fishing effort exerted per day per unit vessel towards the end of the last phase will, to a larger extent, be compensated for by the decommissioning of older fleet units and of those that are unable to compete successfully in a less favourable environment. Towards the end of this stage, the departure of older fishing units from the fleet will be accelerated by more frequent mechanical problems and increased repair costs, which will begin to bring down the effective number of fishing days in the season for a given fleet size. A decline in the total landings at this stage will probably lead to increased market prices. If this occurs, it is possible that the artisanal fishery may experience a resurgence by capitalizing on its lower costs and on the existence of an expanded market and perhaps also on the improved availability of rather larger size groups to line and trap fisheries, as opposed to less selective (e.g. trawl) methods. In contrast to the first phase, we may now find some of the better young fishermen moving into the artisanal fishery and building new boats at the same time that the age of both boats and fishermen in the industrial fishery is increasing. This improved economic performance of the small-scale sector may then lead to another investment cycle, as the industrial sector and the more successful artisanal fishermen reinvest in larger industrial vessels in response to higher prices and abundance.

"PULSE" FISHING AND ROTATIONAL HARVESTING

We can see the rapidity with which effort can be brought to bear on a new resource in its most extreme form for some distant water fleets. Here the strategy of "pulse fishing" which removes a large part of the fishable population in a few seasons is fundamentally valid only under two presumptions:

1) Either: a) There exist other similar resources that can be harvested in rotation when the present one is cropped down, allowing it time to recover, or b) the economic return from a single cycle is adequate for population collapse of the harvested population to be an acceptable risk.

2) The new year classes that, it is presumed, will enter the fishery several years following pulse fishing under 1-a) will be more likely to reach optimal harvestable size in the same season than under continuous "equilibrium" harvesting, thus avoiding "wastage" due to harvesting a mix of age groups, some of which are harvested before or after the optimum age.

This latter point is presumably the basis on which some theorists have argued for this being a more efficient form of harvesting from a yield-per-recruit point of view. The following considerations suggest that, although this may have been logical for long-range fleets in the early days of distant water fishing, it should be applied with caution within any given national jurisdiction:

a) Properly applied, it presupposes the existence and feasibility of at least as many rotationally closed areas as the mean number of years in the life span of the species from birth to harvesting (and reproduction). (If recruitment fails in a given year, this will be of course too few years!) One other prerequisite is that the fleet size needed be relatively small, but property rights to the resource exclusive and properly enforced. Apart from some intertidal fisheries (e.g. oysters, clams), this seems rather infeasible unless the population density of fishermen is very low.

b) The impact of such intensive harvesting may lead to species-successional changes which result in some (less desirable?) species filling the vacant niche.

c) Especially if b) occurs, the disruption of employment and of supply and markets and of the return on existing plant, that failure of this system implies, may be unacceptable.

SELF-REGULATORY MECHANISMS

In the absence of a formal management system controlling entry to the fishery, effort expanded or total removals (quotas), it has already been suggested that fishing cycles will be initiated by periodic rapid over-investments, leading to oscillation in the system and consequent economic failure or emigration of a significant proportion of the fishing units later in the cycle. In this sense, the system is self-compensatory but is likely to lead to disruptions in the biological system supporting the fishery, not all of which may be reversible in the short term. If we are discussing a 'mature' fishing area where fleet diversification is already well advanced, or an area where the peak periods of production from different resources are in phase with one another, transfer of vessels between component fleets may not be easy, particularly for those economically less efficient units displaced from the main fishery, since the skills, fishing gear and specialized boats needed to compete in an existing fully developed but different fishery may not be adequate. We may even suggest that the frequently suggested panacea for overfishing, namely diversification into other fisheries, is much less possible than formerly and stems from some rosy "racial memory" of pre-EEZ times, when vessel mobility between resources and areas was much easier for the industrial fishery. Even in the (progressively less frequent) cases where unexploited resources exist, there will be a whole range of specialized handling and marketing problems to overcome in addition to problems with the mechanics of effective capture.

In general, multi-purpose fishing ventures would seem to have a better chance of retaining stable earnings and be less likely to perturb the production system than individualized single-species fisheries. Paradoxically enough, however, fishing methods and gear that are more selective in the size and species harvested may allow a better 'control' of the overall multi-species resource, by selectively cropping down the species that are highly abundant in a given year, without wasteful and excessive rates of harvesting being exerted incidentally on a "by-catch" species that happens to be less abundant in a given year.

If the inevitable mismanagement that occurs from time to time, even with the best intentions, is likely to lead the fishery into an over-investment situation, multipurpose vessels and fishermen offer some possibility of diverting effort. Contrarywise, it may be useful to adopt policies that encourage multiple livelihoods such as the farmer-fishermen, so that effort may be diverted at such times without undue economic hardship.

THE CONCEPT OF FISHERIES EQUILIBRIUM IN MULTISPECIES FISHERIES

If we have found some difficulties in postulating the existence of an equilibrium condition in single-species fisheries, this difficulty is further emphasized when the separate elements of a multispecies fishery are considered.

Even if we take the unrealistic but simple concept of a multispecies fishery as a sum of the resultants of a series of individual fisheries, each with their individual response to fishing, we soon run into difficulties as illustrated in Figure 9. Clearly (in the case of a symmetrical, e.g. Schaefer model), we only need to exceed $2f_{MSY}$ for the most 'fragile' species for the "reversibility" of the system to decreases in effort to be lost. Despite its unreality, this simple model in fact suggests that the maximum combined yield from the system should be attained with a level of fishing effort that is lower than that which drives the most susceptible species to extinction. This appears prudent, particularly since this species may play an important role in the system, but is probably a difficult condition to meet in terms of management. However, ignoring this criterion will almost certainly result in other changes in the species composition of the catch which cannot easily be described as corresponding to equilibrium conditions.

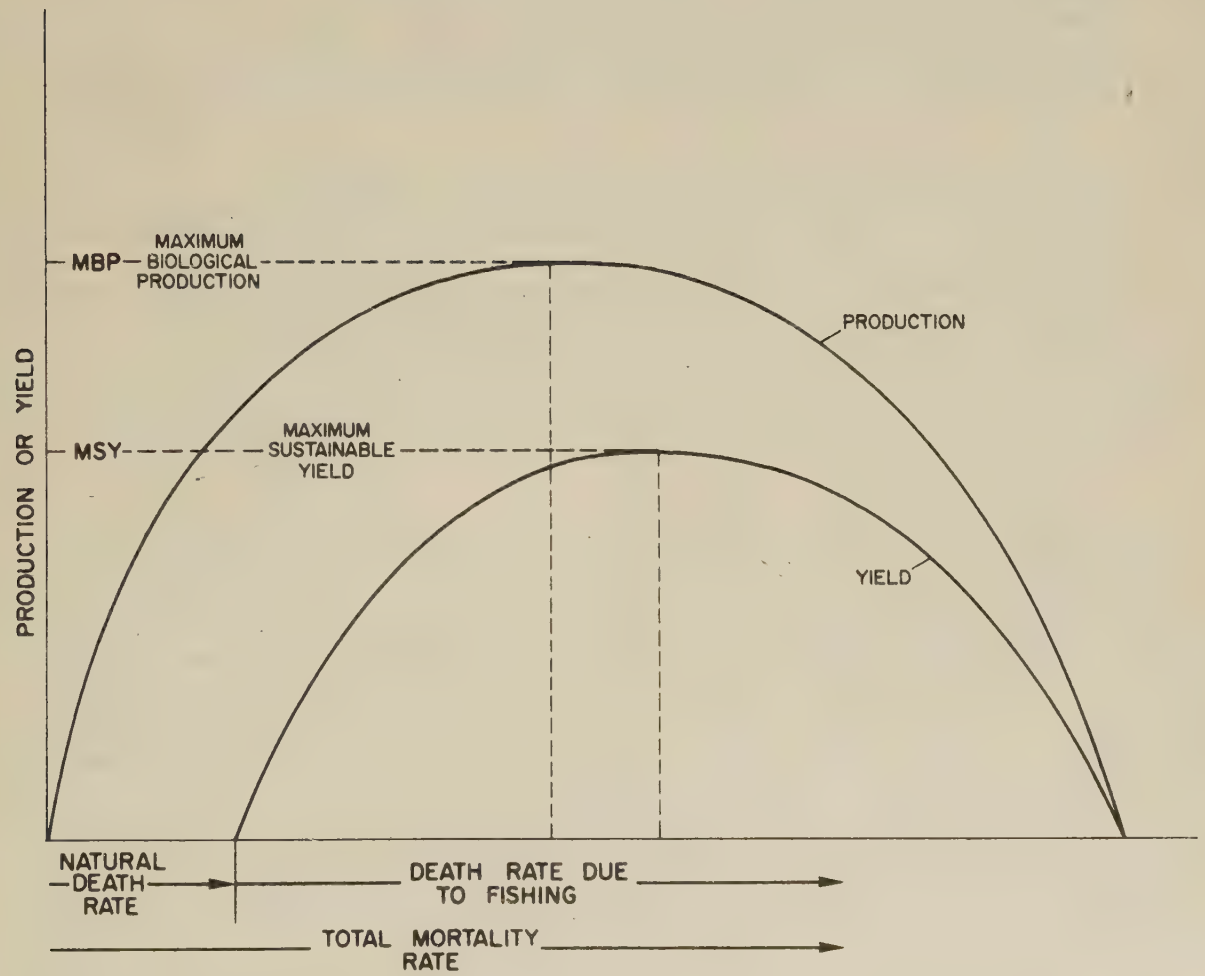


Figure 9

The difference in response to fishing between total production and fishery yield

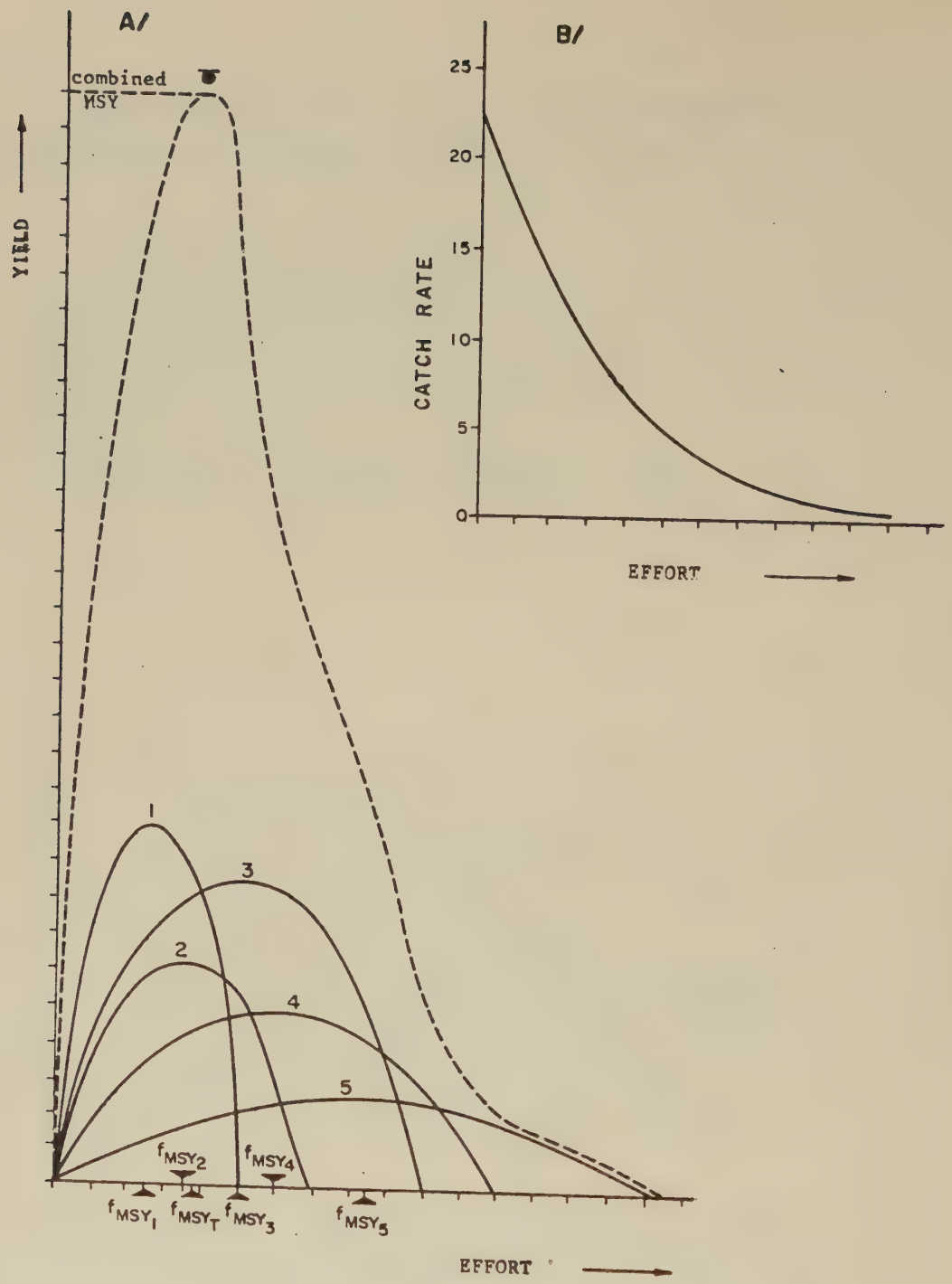


Figure 10

A Illustration of change in overall yield and catch rate in a multi-species trawl fishery with progressive increase in effort, showing how the fishing mortality rate yielding maximum sustainable yield is progressively exceeded for species 1 to 5 in turn as effort increases (from Caddy, 1980).

Note: Beyond f_{MSY} in the example, the reversible nature of the process is presumably lost, since species 1 is now extinct. In this example (and it is probably generally valid) the overall "multi-species MSY" (f_{MSY_T}) is reached early on in the series of MSYs (in this case $f_{MSY_T} = f_{MSY}$).

B A rapid drop-off in catch rate slowing subsequently is predicted with effort, the catch species composition changing continuously with effort.

When we consider biological interactions between the different fish in the catch, the picture becomes almost impossibly difficult if more than two or three species are involved.

One factor that needs to be borne in mind in regulating fishing is that the fishing effort will have an impact not only on the species being harvested but also indirectly on its natural predators, prey or competitors, and the equilibrium between them.

This is because the population size, biomass and age structure of an unexploited resource at any given time is a function of its natural death rate, which in turn is caused by the larger predators in the ecosystem. This resource in turn is a controlling factor on population size of those species making up major items of its food or those with which it competes for food and space. Harvesting the resource will then lead to changes in competition for food and space, as well as changes in species biomass and biological production (production being defined as the amount of biomass incorporated into the body tissues of the species per unit time). This in turn will have impacts on the population size of those other species that interact with it.

This is illustrated in simple fashion by Figure 10, which also suggests one important consequence of fishing beyond the level of maximum biological production of the species or system, which is to the left of the f_{MSY} level. At MSY the total production of the species is declining rapidly, and the decline will be more marked for species earlier on in the food chain whose natural instability is higher. Since a change in production is inevitable with fishing, we can expect some impacts of fishing on species to be inevitably transmitted through the food web to those other species trophically linked with it.

Figure 11 shows, in perhaps its simplest form, the kind of effects that can occur when one member of a food web is harvested. In this hypothetical example, a group of seven species are linked together as predators and prey by arrows showing the direction of movement of prey biomass being consumed and then incorporated into the generally smaller biomass of predators, finally ending up in the biomass of the top predator A. The diameters of the circles around each species are intended to be proportional to their biomass, and in the unfished population (Figure 11-A), we can see that, because roughly 75-90 percent of the food energy consumed is wasted or lost as heat during the energy transformations needed for biological functions such as swimming, excretion, etc., the size of the predator populations generally declines as we go upwards in the food web. It is also supposed in Figure 11-A, as indicated by the dotted lines, that the two species E and F show another type of interaction, either competing for the same food or for the same space (ecological niche).

Supposing now that an intensive fishery begins on species C, what general types of interactions are likely to occur? Firstly, if the biomass of C is significantly reduced, C will have less of an impact on the biomass of its prey species, in particular on species F and G. These may be liable, therefore, to eventually show an increase in population size if no other intermediate predator emerges. Because the population of F may now be competing more vigorously with species E for space or food, we may later see a decline in biomass of species E. Theoretically, this perturbation would be propogated indefinitely through the multitude of linkages in the marine food web, which are not all shown in Figure 11. In fact it seems likely that, unless the species in question is a key 'substrate' species for the whole community, the impact of fishing should die off rapidly with distance along the linkages of the food web. One reason for this (perhaps rather rash) statement is the multiple linkages in marine food webs (shown as short arrows in Figure 11) representing alternative unspecified food items for each species. A small increase in the proportion each species forms in the diet of any given predator could make up some of the "shortfall" due to over-exploitation of either its prey or of its prey's prey! The elasticity of food webs to these kind of effects is rather variable and, although in some systems almost complete elimination of a given predator by fishing (e.g. pike) may have little noticeable effect, since a smaller predator (e.g. larger perch) may move in to occupy its niche, in older more structured communities, e.g. coral reef or mangrove swamp fisheries, the "division of labour" between species is much more developed and heavy fishing on some components can have widespread impacts.

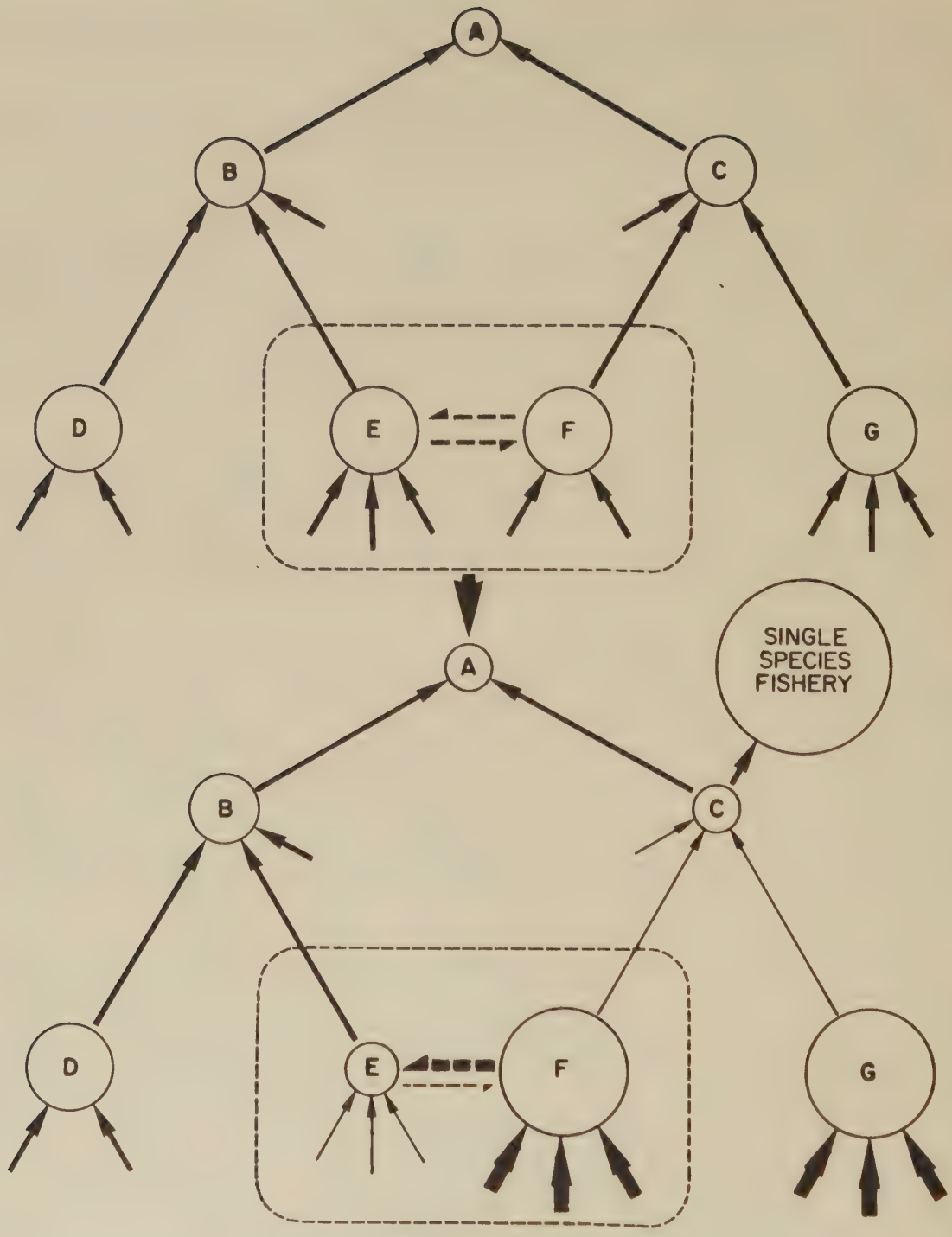


Figure 11

A. Simple unexploited food web for species A-G; solid arrows show flow of biomass from predator to prey with diameter of circles corresponding to species biomass. (Solid arrows without origin correspond to unspecified prey species, and dashed arrows inside dotted outline indicate competition between species E and F for space, food, etc.)

B. A monospecific fishery for species C is now in operation. The thickness of arrows is proportional to rate of flow of material from prey to predator or, conversely, degree of control exerted by predator on prey.

CONCLUSIONS

Granted that a great deal more could be done to document the point of view expressed here, it seems to suggest the following practical consequences that can be compared against the experience of fisheries managers:

1) We cannot expect species close to the bottom of the food chain and/or dependent on only one or two main food items to necessarily show roughly constant population sizes or to be manageable exclusively on the basis of equilibrium models. Information on the environment and the incoming level of recruitment will be essential for these kinds of species. Especially for short-lived pelagic species in oceanographically unstable regions, we can expect populations to show very wide fluctuations in numbers.

2) Fluctuations in biomass and, even more so, in production will tend to be "damped out" somewhat as we move towards the top of the food chain (e.g. cod, tunas, hakes, halibut, groupers, etc.) so that near-equilibrium conditions may be more safely assumed to apply for these organisms, especially if they are multi-age-group species.

3) All other things being equal, stocks of fish close to the centre of their range and remote from areas of environmental instabilities (e.g. upwelling zones), and which are not reliant on only a few food items, will tend to be less liable to population instabilities and be more 'manageable' using equilibrium yield models than the converse case above.

4) A more or less regular fluctuation of abundance may show up in fisheries landings from stocks of many species which are otherwise relatively stable in population size. Apart from long-term changes in environmental parameters that can affect stock size directly or via population of predators, prey or competitors, a second major cause of fluctuations or fisheries cycles in landings is caused by periodic over-investment in fisheries. These two types of consideration do not necessarily act independently, nor are they easy to distinguish. Concentrating now on those fisheries for species whose unfished populations are relatively stable, but which show periodic fluctuations (as a fisheries 'cycle') under exploitation, the following working hypotheses are proposed for discussion:

   - One extra unit of fishing effort or one unit of investment expended on vessel and plant construction will not yield the same results in each of the various phases of the fisheries cycle described.
   - If this is so, and it certainly merits discussion, recognition even roughly of the current phase of the fishery is of potential benefit to both the participants as well as the managers of fisheries.

5) A second prediction stems from the observation that a degree of overshoot of effort in early stages of the investment cycle is inevitable, particularly if the effort build-up is too rapid to determine its impact on the resource. This prediction can be expressed as follows:

   - The degree of departure from "equilibrium" conditions and the amplitude of subsequent perturbations in the exploited system will be related to the rate of increase in fishing effort and mortality and the rate of investment during the expansion of a fishery. A visual analogy to this statement can be seen in Figure 12, which shows a transition to periodic population 'crashes' with increasing intensity of fishing, particularly if applied during the early expansion phase of the fishery. Similar effects can also occur if environmental changes affect the carrying capacity of the environment on the annual recruitment.

- In fact, the initial investment phase, if slowed and spread over a number of years with time for feed-back to occur, will for those otherwise more stable fisheries reduce the possibility and extent of effort over-runs.

6) Although the speed of mobilization of effort has increased, the response time for managerial action is still slow. Such long lag times can be shown to have a significant feedback in causing cyclic behaviour in the fishery system.

7) If the above principle is correct, it suggests two things:

- That the time scale that fisheries managers should envisage operating within should be considerably longer than the usual day-to-day management "adjustments" that occupy so much of a manager's time, and should be more related to the half-life of the oldest components in the system (the boats and the fishermen).

- That the most important and far reaching decisions are made in the expansion phase of the fishery, because of the existence of a so-called "rachet principle" in fisheries systems. The rachet principle notes that it is far easier to increment the number of vessels in the fleet and the effort they exert than to remove them when this input proves unfavourable. This stems from the fact that: a) the average working life of vessels and the fishermen that crew them are in excess of the average duration of life cycle of the resource they are harvesting, and b) that the alternatives for alternative employment of fishermen (or vessels) are now generally very limited, especially within smaller EEZs or other national management units.

8) Although little attention has been paid to the question of the average life time an individual vessel spends in a given fishery, we may hypothesise that the "survival curve" for a particular type of vessel to a given fishery will reflect the past degree of stability as well as the rate of renewal of investment over the past period of years. Thus, an age spectrum of boats where many are of the same age should indicate a more broad cyclic or unpredictable fishery than if the number of boats falls off steadily with age, due to a steady decommissioning or emigration to other fisheries being balanced by a constant rate of replenishment by new boats.

This leads to one other observation, namely that devoting some time to analysing the characteristics of the fleet (and the crew), in designing statistical systems for a fishery, would give a better perspective to the information collected. This applies particularly to the collection of economic information, since the rent extracted from a given resource by a particular fishing or processing unit can presumably only be determined if all costs and expenditures over its life span are considered. To attempt to obtain information either exclusively from the early expansion phase, when catch rates are high but rates of capital investments are also high or, alternatively, from the later phases when catch rates may also be recovering but costs of repairs and problems with crew turnover are quite different, will not in either case provide a clear picture of what is going on. In this sense, the idea of economic sampling within a fisheries cycle, in which a group of vessels entering a fishery during a brief period of years are followed as a unit throughout their life span in the fishery, should give a better chance of arriving at unambiguous answers on the economies of the system.

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Appendix

A TENTATIVE CLASSIFICATION OF FISHERIES

Examples of each of the four categories are given in Figure 1 of the Appendix as a series of landing trends. First it was rapidly evident from even a short survey of the literature that, outside a few limited areas in the North Pacific and Atlantic (of which the North Sea makes up 75 percent of the cases), we have very few long-term series of landing data (over 40 years) for other parts of the world. As a result, we are still basically ignorant about the 'typical' long-term chain of events in fisheries from most of the areas of interest to developing countries, and hence any classification system such as proposed here is necessarily very tentative. Four categories are proposed for consideration:

1. "Steady State" Fisheries

This group of fisheries fits most closely the underlying equilibrium assumptions behind conventional fisheries theory. Examples include mixed groundfish fisheries in the North Atlantic, particularly the North Sea, and even some (but not all) individual species making up these fisheries. Even these fisheries are not immune from extrinsic perturbations caused by socio-economic factors, wars, overfishing and recruitment, but basically the biological production system is here relatively robust or fishing intensity relatively low or constant.

Example A - The North Sea Turbot Fishery :

Occurring principally as an incidental catch to other flatfish fisheries in the Eastern North Sea, the existence of a rather complete time series of catches shows rather nicely (Figure 1a of Appendix) some of the classic predictions of yield theory, namely a rise in landings due to pauses in fishing (the 2 World Wars), followed by a rather rapid decline to long term "equilibrium" fishing. The long-term landing trend (Weber, 1979), showing a gradual increase followed by a slow decline, again fits very nicely the classic picture of a resource yield responding positively then negatively to increasing effort which eventually exceeds that yielding the MSY for the stock.

Example B - Georges Bank Haddock :

Although fluctuations in landings of $\pm$ 50 percent of the long-term mean have been observed in this fishery, which has had a relatively irregular recruitment history, the general level of landings remained fairly steady until the abnormally large recruitment of 1964, which led to rapid increase in effort to well in excess of f_{MSY} levels, followed just as rapidly by a collapse in the stock, leading to quota and other regulations on removals beginning in 1970. The point being made here is that, although management under equilibrium conditions was probably practical prior to 1964, this approach to managing the fishery will not again be possible until stock recovery is close to complete (Fig. 1B adapted from Clark and Overholtz, 1979).

Example C - Total North Sea Fish Landings :

It is characteristic of landing trends for many multispecies fisheries that they are less variable than most of the individual species components, although, as for Example A, the two interruptions due to the World Wars are again evident (Holden, 1978). The large peak beginning in the late 1960's appears to reflect the change-over in dominance from pelagic to demersal biomass that occurred around about this time.

2. Periodic Regular Fluctuations

Example D - Baleares Hake Fishery :

A strong periodicity in landings has shown up since 1940 for this and other species in the western Mediterranean, which is sufficiently regular for hake that a simple sine function with 13-year period is a reasonably adequate description of the landing trends (Figure 1-d of Appendix). The most likely explanation for the periodicity seems an extrinsic one: regular fluctuations of similar period have shown up in indices of solar activity. From the perspective of fisheries cycles, the period is sufficiently long that we can reasonably suppose that new entries to the fleet will tend to occur in the early period of each new cycle of abundance.

Example E - Bay of Fundy Scallop Fishery :

A 50-year series of data on this fishery for total landings and fleet size showed that much of the variation was due to a 9-year periodicity in scallop abundance (Caddy, 1977). An explanation in terms of extrinsic long-term tidal phenomena was proposed (the Bay of Fundy has close to the highest tidal range in the world). Again a simple sine function with changing amplitude was a reasonable description of landing trends and has proved a reasonable predictor of subsequent years of peak landings since put forward in the early 1970s. Here, there is evidence that peaks in fleet size lagged behind peaks in production for each cycle, as would be expected if new vessel entry followed early years of good abundance.

Example F - Californian Dungeness Crab :

These fisheries show a regular periodicity of about 10 years in the catch which so far has not been explained but is believed to be due to effects of environmental factors on recruitment and possibly also on availability to fishing (Methot and Botsford, 1982).

Example G - The Russian Pacific Fishery for the Saffron Cod (Eleginus gracilis)

In the Sea of Japan there is a fishery with a 13-year periodicity in the catches, superimposed on longer-term upward and downward trends in average production. Vasil'kov et al. (1982) attribute both the fluctuations and long-term trends to cycles in solar activity which have a similar periodicity, and refer to papers by other Russian workers on other Pacific and Atlantic stocks of cod, salmon and herring, for which various periodicities in landings have also been determined.

3. Fluctuations With Irregular Periodicity

This group probably contains the largest number of fisheries, although the explanations for the irregular (aperiodic) fluctuations in landings are sufficiently diverse that broad generalizations are difficult to make. Explanations may range from intra- or inter-specific species interactions and the recruitment fluctuations they produce, predator-prey models (with the fishery as the main predator - see earlier text), to environmental or economic fluctuations that do not show any particular periodicity.

Example H - The Norwegian Fishery for Juvenile Herring :

A series of five major peaks in landings occurred over a 40-year period (1930-1970) in this fishery that presumably corresponded to periods of better than average herring abundance or availability. The explanation for the earlier peaks in this fishery for predominantly juvenile herring is not available to the author, but Dragesund et al. (1980) indicate that the last and largest peak that preceeded collapse of the fishery corresponded to the introduction of ring net fishing techniques, thus fulfilling the conditions for a final (and catastrophic) fishing cycle.

Example I - Gulf of St. Lawrence (Magdalen Is.) Lobster Fishery :

An isolated fishery for lobsters where production has been shown to be correlated with the extent of annual freshwater run-off from the St. Lawrence Estuary at the time of reproduction. Heavy exploitation of an irregularly recruiting stock, largely harvested in its first year in the fishery, is probably responsible for wide landing fluctuations. Overall production cycles were initiated however in the early post-war years and in the late 1950s, coinciding with the increase in minimum carapace size, which increased potential yield to the fishery (Sylvain and Boudrealt, 1969).

Example J - The Georges Bank Scallop Fishery :

Several cycles are evident in the history of this offshore fishery: the first beginning in the 1930s with predominant participation by inshore-style vessels, the next major peak in landings in the mid-1940s begins with major US investment in offshore vessels. Following several good years of abundance, a new Canadian offshore fleet took over a large share of the harvest in the 1960s and 1970s. In the late 1970s and early 1980s, US offshore vessels from fisheries to the south of Georges Bank entered the fishery over a short period of years to initiate a new cycle of events (figure adopted from Serchuk and Wood, 1978).

4. Fisheries Showing Environmental and Ecological Instabilities

Several different mechanisms can be proposed for fisheries in which marked irregularities in production can occur, and historically these have also been shown in otherwise stable fisheries subject to massive over-exploitation (e.g. pulse fishing).

Considering, however, only those fisheries where factors other than just rapid stock depletion are the source of irregularities, we can recognize two main (but interrelated) types of causes: due to the direct effect of instabilities of the environment (as for example when oceanic current or upwelling systems move geographically or show amplitude fluctuations), and to biotic factors where competition, predation or disease results in one species being supplanted by another.

From a management point of view, these types of fisheries present serious problems. On the one hand, over-investment early in a new cycle of such unstable fisheries may prevent loss of harvestable biomass but leave a large investment in plants and boats idle following the fishery collapse. Alternatively, an over-cautious policy will lose significant possibilities for harvesting the stock. A two-tiered policy of moderate local vessel construction and joint-venture charter or licensing of non-national vessels seems appropriate here.

Example K - The California Pelagic Fisheries for Sardine and Anchovy :

A number of very large pelagic fisheries in different parts of the world have shown switches in dominance between one species and another, of the kind shown in Appendix Figure 1-k between sardine and anchovy (taken from Daan, 1980). Close proximity to a centre of biological production is the usual setting for such fisheries, such areas and such species close to the bottom of the food chain being particularly liable to instabilities. To some extent, the harvesting of these alternate resources can often be by means of the same fleet, although fishing methods and markets can differ, and mean that the change-over period effectively initiates a new 'cycle'. The possibility of periodic catastrophes with or without fishing may exist.

Example L - The Japanese Sardine Fishery :

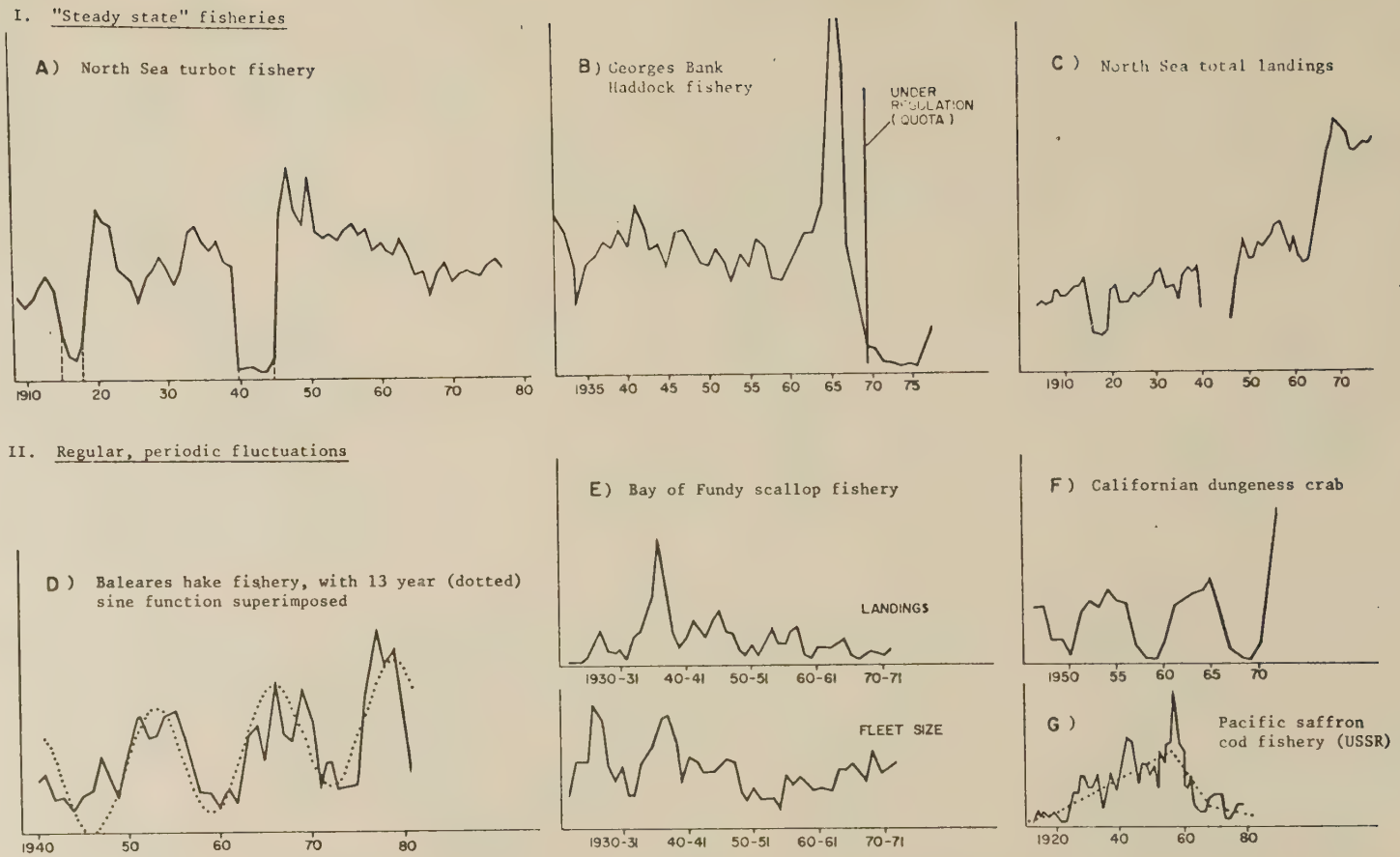
A notably variable oceanic system, that associatied with the Kuroshio and Oyushio current system, which come fairly close inshore on the Japanese islands in some years, also show characteristic patterns of meandering that have been documented by Japanese scientists and have a pronounced influence on production in some key fisheries, particularly those for pelagics such as sardines (e.g., Kondo, 1980). As is evident from Appendix Figure 1-l, these effects are wide-spread and synchronized over a wide area, so that movement of boats to adjacent fisheries is not always a practical solution following collapse of a local fishery. Similar major current and upwelling systems with variable behaviour and influence on production are known, in particular that due to El Nino off Peru whose impact on the major local fishery for anchovies has been widely discussed.

Example M - The New England Shrimp Fishery :

Fisheries for species close to the fringe of their range may be expected to be more sensitive to environmental factors. Here, fishing for an Arctic species of shrimp is only possible in the southern part of its range when winter temperatures are low for a series of years, allowing stock build-up (Clark et al, 1979). This type of fishery is rather predictable and the requirement for control of fishing effort specifically for conservation of this type of species is secondary to the need to avoid economic losses due to over-investment in a temporary resource.

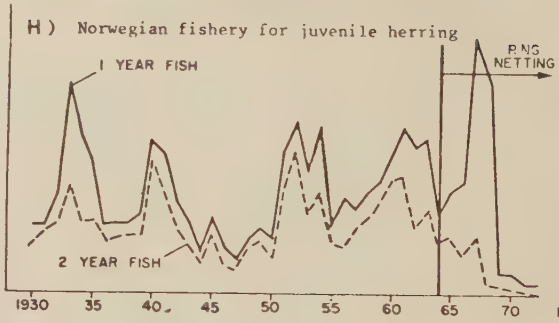
Example N - Pelagic Fisheries of the ICNAF Area :

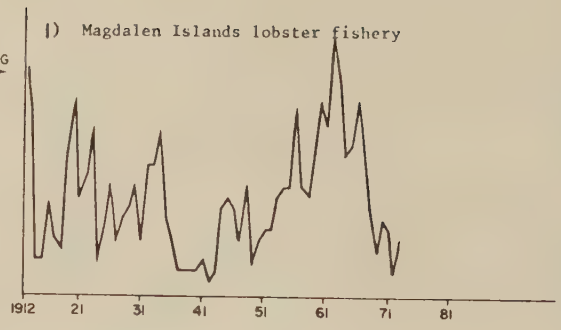
Appendix figure I(N), from Schumacher (1980), is an example of how the possibility of applying high fishing intensities and switching rapidly between resources can result in successive peaks in production, in what may otherwise have proved relatively stable and sustainable fisheries if fishing intensity had been more moderate and invariant. Some major resources (e.g. Georges Bank herring) have suffered total extinction in this period, while for others (e.g. capelin stocks off the north-east coast of Canada), following initial heavy over-exploitation, the fisheries are now being more closely restricted. The point to be noted here is that steady state models are rather difficult to apply to these very intensive and short-term changes in fishing process. Many fisheries commissions dealing with industrial fisheries now have to place heavy reliance on direct measurements of annual stock size and recruitment, in an attempt to keep up with these types of accelerated exploitation patterns, rather than using models postulating existence of equilibrium conditions. The problem is that the principal tool for analysis of irregular populations where age composition is known is cohort analysis. However, this method is most uncertain for recent years, when management advice is mainly generated, and gives little guidance for the immediate future.

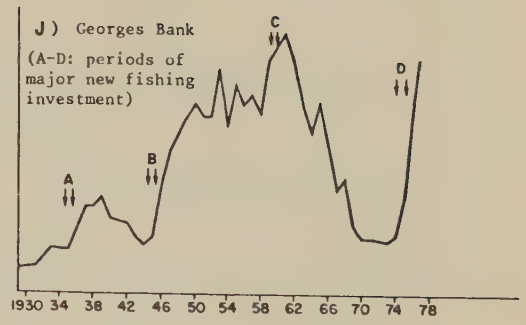

I. "Steady state" fisheries
A) North Sea turbot fishery
1910 20 30 40 50 60 70 80
B) Georges Bank Haddock fishery
UNDER REGULATION (QUOTA)
1935 40 45 50 55 60 65 70 75
C) North Sea total landings
1910 20 30 40 50 60 70
II. Regular, periodic fluctuations
D) Baleares hake fishery, with 13 year (dotted) sine function superimposed
1940 50 60 70 80
E) Bay of Fundy scallop fishery
LANDINGS
1930-31 40-41 50-51 60-61 70-71
FLEET SIZE
1930-31 40-41 50-51 60-61 70-71
F) Californian dungeness crab
1950 55 60 65 70
G) Pacific saffron cod fishery (USSR)
1920 40 60 80

Appendix Figure 1: Some examples of long-term landing data, illustrating a tentative classification into 4 main types of fishery

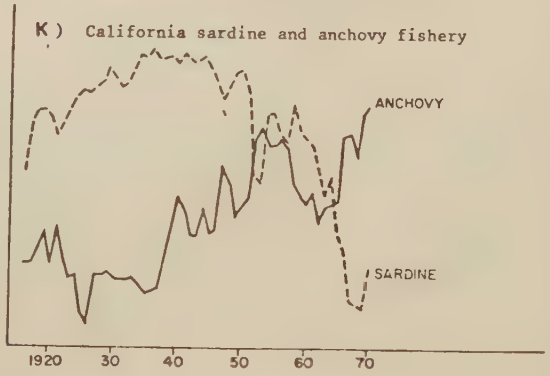
III. Fluctuations with irregular periodicity

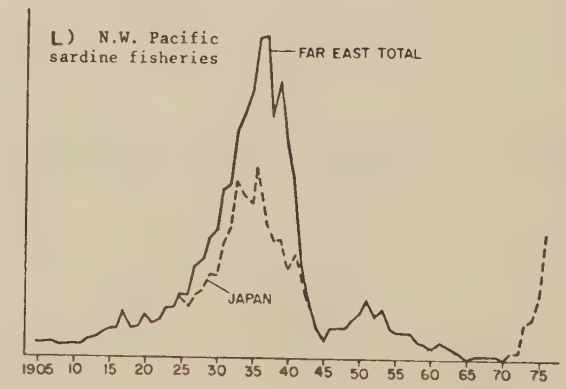


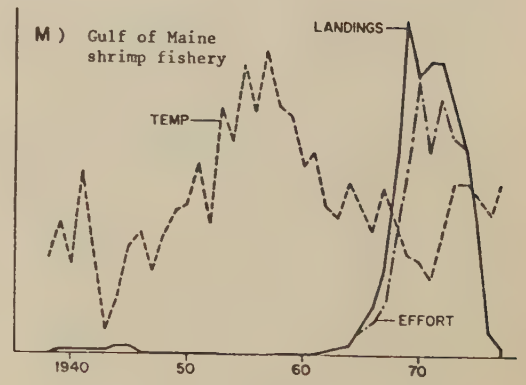


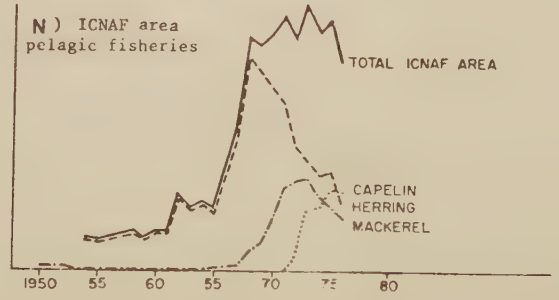


IV. Irregular (intermittent) production









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